UNCLASSIFIED

AD NUMBER

AD856021

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; FEB 1969. Other requests shall be referred to Rome Air Developmental Center, Griffiss AFB, NY.

AUTHORITY

USAF ltr, 27 Aug 1973

THIS PAGE IS UNCLASSIFIED

RADC-TR-68-403
Final Technical Report
February 1969

RELIABILITY PREDICTION - MECHANICAL STRESS/STRENGTH INTERFERENCE (NONFERROUS)

Charles Lipson
Narendra J. Sheth
Ralph L. Disney
Mehmet Altun
University of Michigan

This document is subject to special export controls and each transmittal to foreign governments, foreign nationals or representatives thereto may be made only with prior approval of RADC (EMERR), GAFB, NY 13440.

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

462

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded, by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Do not return this copy. Retain or destroy.

RELIABILITY PREDICTION - MECHANICAL
STRESS/STRENGTH INTERFERENCE (NONFERROUS)

Charles Lipson
Narendra J. Sheth
Ralph L. Disney
Mehmet Altun
University of Michigan

FOREWORD

This report is the result of a study performed by the University of Michigan, Department of Mechanical Engineering, Ann Arbor, Michigan, from March 1967 to August 1968. The research team was headed by Professor Charles Lipson, actively assisted by Mr. Narendra J. Sheth, Associate Research Engineer. Mr. Sheth was instrumental in developing the techniques and methods required for the project and headed the group responsible for the data collection and the development of the computer approach used in the data analysis. Mr. Mehmet Altun contributed significantly toward the development of the computer approach and the data analysis. Professor Ralph L. Disney of the Department of Industrial Engineering developed and evaluated the analytical expressions of the interference.

The following contributed to the various phases of the project: Messrs. Raymond B. Pittman, John P. Godwin and Edward J. Gainer.

The study was performed for the Rome Air Development Center under contract F30602-67-C-0204, Project 5519, Task 551902. The RADC project engineer was Mr. Donald W. Fulton (EMERR).

The distribution of this document is limited under the U. S. Mutual Security Act of 1949.

This report has been reviewed and is approved.

Approved: DONALD W. FULTON
Reliability Engineering Section
Reliability Branch

Approved: WILLIAM P. BETHKE
Chief, Engineering Division

FOR THE COMMANDER: IRVING J. GABELMAN
Chief, Advanced Studies Group

ABSTRACT

This study addressed itself to the development of a Stress/Strength Interference Theory in form of a practical engineering tool, to be used for designing and quantitatively predicting the reliability of mechanical parts and components subjected to mechanical loading.

In our past investigation ("Reliability Prediction-Mechanical Stress/Strength Interference Theory" by Charles Lipson, Narendra J. Sheth and Ralph L. Disney; Final Report RADC-TR-66-710, March 1967, referred to in the present report as Reference 1) the Interference Theory was developed for the ferrous materials. In the present study, the work was extended to non-ferrous materials.

Early practices in stress-strength relationship dealt almost entirely along the lines of factors of safety. Utilization of such factors is justified when they are based on considerable experience with parts not too different from the one under consideration. However, when substantial changes in the geometry, the processing, or the function of the part are contemplated, a major error may result if the old factors of safety are projected to the new set of conditions.

In the present investigation, an approach was used which attempted to recognize the above limitations. Instead of an indiscriminate grouping of all the variables affecting stress and strength (generally fatigue strength) into one index (factor of safety) these variables were individually recognized. The principal variable is the scatter in the stresses imposed on the part and in the strength of the material resisting these stresses.

The prevailing practice is to use the mean values of the calculated stress and strength, ignoring the natural scatter that each may possess. However, the variability in these two factors results in a statistical distribution of stress and strength. When these two distributions interfere, that is when stress becomes higher than strength, failure results. Means of expressing these distributions, in a practical engineering sense, and means of calculating the resulting interferences, represent the heart of the present study.

In our past investigation(1) on ferrous materials, the problem of determining the scatter in the fatigue strength and, subsequently, its distribution function was resolved by a graphical method. Among the several distribution functions that were considered, only the Weibull distribution was used because of its wide use and the difficulty of handling other distributions by a graphical method.

In the present investigation on the non-ferrous materials, a computer approach was developed which made the determination of the distribution functions of fatigue strength considerably less difficult (Section 6). Consequently, several distributions were tried: Weibull, Largest Extreme Value, Smallest Extreme Value, Logistic and Normal. The reasons for the selection of these particular distributions are given in Section 6.3. It was later found that the Logistic distribution had similar characteristics to the Normal

distribution and therefore it was not followed any further.

Mechanical Properties Data Center in Traverse City, Michigan, was found to be a very useful source of information for the fatigue strength data for various non-ferrous materials under various conditions such as the type of loading, surface finish, stress concentration, heat treatment, temperature, environment, etc. Considerable fatigue data thus obtained were then organized and systematized according to materials and conditions.

A computer program was developed so that when these data (raw S-N data) were fed into the program, the computer printed out the degree of fit and the parameters for all the distribution functions tried for any given set of fatigue strength data.

In the first part of this program, the scatter in life was converted into the scatter in strength. In the second part, the distribution functions (Weibull, Normal, Logistic, LEV and SEV) were fitted to these strength data. The best fitting distributions (those with the highest degree of fit) and their parameters were then chosen, and these are presented in a tabular form in Appendix 1 for various non-ferrous materials and under various conditions.

In order to present these data in a pictorial, and thus more easily digestible form, the representative parameters were then plotted on log-log scale against life for various materials and conditions (Section 6.7). In order to put this information on the same consistent basis, all the data were expressed in terms of the same distribution (Normal). The plots were made by expressing the mean (μ) and standard deviation (σ) as a function of life (Section 6.7). The reasons for the selection of the Normal distribution for these graphs, the description of the computer approach, and the statistical tools used in developing this approach are given in Section 6.

The problem of stress distribution (Section 7) was investigated in more detail than in the previous study[1], but no additional information was located. When one speaks of "stress distribution" he usually refers to a spectrum of loading or stresses to which a part is subjected. Indeed, most of the available data on the subject is expressed in this manner. In an engineering sense, this kind of a distribution means the number of times that a given part is subjected to a given load or stress. In the Interference Theory however, this is not what is wanted. For consistency with the strength distribution, the number of parts subjected to a given stress is required instead.

In the present investigation, the required stress distribution was obtained in the same manner as is our past study. This was done by converting the stress spectrum, which generally has some mean stress, into a spectrum with zero mean, with the aid of the Goodman diagram. This facilitated the conversion of the resultant spectrum into an equivalent stress based on zero mean stress. The conversion was accomplished by means of Miner's rule. The required stress distribution was then expressed in terms of the equivalent stress. This distribution was then compared with the strength distribution to determine the probability of interference.

Most investigators in the past have assumed both the stress and strength distributions to be normal. In those cases when they were not normal, a Monte-Carlo technique was employed. This involved a sophisticated means of randomly selecting a sample from one distribution and comparing it with a sample from a different distribution.

In view of the serious limitations of the Monte-Carlo technique, a method of Integrals was developed (Appendix 3) and used in the present study. This method involved developing an integral resulting from the interference of two distributions and evaluating this complex integral. Numerical analysis was carried out (Appendix 3) using an IBM 360 computer to solve these integrals.

In our past investigation on ferrous materials[1], these integrals and hence the interference values were evaluated and tabulated for the following combinations:

Stress Distribution	Strength Distribution
Normal	Normal
Weibull	Weibull
Normal	Weibull

In the present investigation on non-ferrous materials, data analysis (Section 6) revealed many cases where fatigue strength followed distributions other than Weibull or Normal. Hence, it was necessary to develop tables of interference values for the following additional combinations:

Stress Distribution	Strength Distribution
Normal	Weibull (Extended-see Section 4.2)
Normal	Largest Extreme Value
Normal	Smallest Extreme Value

These interference values (tabulated in Appendix 2) were found to be highly non-linear. Therefore, for the purpose of interpolating these values in a given table or between the tables, it is recommended that a higher order interpolation than linear be used. A suggested method of interpolation, with some solved examples illustrating this method, is given in Section A-2.1.

In order to show the application of The Interference Theory Technique developed in the present study two examples were solved, as described in Section 9.

TABLE OF CONTENTS

EVALUATION

1. This study was concerned with the development of a practical engineering tool to be used in predicting the reliability of mechanical parts fabricated of nonferrous metals and subjected to dynamic loading. The tool was to be compatible with the Stress-Strength Interference Theory as reported in RADC-TR-66-710 and be usable by design engineers with limited statistical background.

2. The study has provided a prediction technique which is almost "cook-book" in nature and requires a minimum amount of computation except as required in the interpolation of the tabulated interference values. The tabular values are highly nonlinear; thus, linear interpolation cannot be used. Procedures for higher order interpolation are given and illustrated. Within the limitation that the material must be a nonferrous metal, the reliability of any part subjected to fatigue loading can be predicted. Examples of such parts would include springs, fasteners, shafts, beams, torsion bars, vehicle frames and suspensions, forgings and castings. The accuracy of the technique depends on the knowledge the user has of the stress distribution, i.e., measured or estimated.

3. The results of this study and of the earlier study of ferrous metals will be combined and presented in the RADC Nonelectronic Reliability Notebook.

Donald W. Fulton
DONALD W. FULTON
Reliability Engineering Section
Reliability Branch

SECTION 1 INTRODUCTION

A complete cycle of reliability is made up of four stages; 1. Specification of Reliability; 2. Prediction of Reliability; 3. Verification of Reliability; 4. Preservation of Reliability. The heart of the second stage, namely, the Prediction of Reliability, is the Interference Theory.

The basic idea behind reliability is that a given part has certain physical properties which, if exceeded, will result in failure. The factor which may cause these properties to be exceeded is the stress imposed by the operating conditions. Thus, in prediction of reliability it is not the stress alone or the strength alone that is the determining factor but the combined effect of the two.

Early practices in stress-strength relationships dealt almost entirely along the lines of factors of safety. Once a part was designed and the ratio of strength to stress was in the range of approximately 5 to 10, it was considered to be safe for service. In certain industries and in certain applications, factors of safety as high as 20:1 were employed.

The definition of the factors of safety varied from user to user, depending on the sophistication and the complexity of the problem.

Some of these definitions, found in literature, are listed below:

$$\text{Factor of Safety} = \frac{\text{Ultimate Strength}}{\text{Nominal Stress}}$$

$$\text{Factor of Safety} = \frac{\text{Yield Strength}}{\text{Nominal Stress}}$$

$$\text{Factor of Safety} = \frac{\text{Ultimate Strength}}{\text{Actual Working Stress}}$$

$$\text{Factor of Safety} = \frac{\text{Yield Strength}}{\text{Actual Working Stress}}$$

$$\text{Factor of Safety} = \frac{\text{Maximum Safe Load}}{\text{Normal Load}}$$

$$\text{Factor of Safety} = \frac{\text{Computed Strength}}{\text{Computed Load}}$$

$$\text{Margin of Safety} = \frac{\text{Strength-Stress}}{\text{Stress}}$$

$$\text{Design Factor} = \frac{\text{Strength}}{\text{Design Stress}}$$

$$\text{Factor of Utilization} = \frac{\text{Stress}}{\text{Strength}}$$

$$\text{Functional Reserve Factor} = \frac{\text{Magnitude of Variable Producing Failure}}{\text{Magnitude of Variable at Operating Conditions}}$$

where the variable could be force, power, torque, material, surface finish, fillet radius, etc.

Apparently the factor of safety was meant to account for all the variables which were known to affect the stress and strength of the member. The utilization of a factor of safety of this kind has justification only when its value is based on considerable experience, with parts not too different from the one under consideration. However, when substantial changes in the geometry, the processing, or the function of the part are contemplated, a major error may result if the old factor of safety is projected to the new set of conditions.

This can be illustrated by the problem of automotive axle shafts which were failing in service in large numbers. These shafts had been fabricated from a steel with a tensile strength of 240,000 psi, and yet, the operating stresses as measured in actual service were found to be only 13,000 psi. This produced an apparent factor of safety of 240,000/13,000 = 18.5. This is obviously a fictitious value, since the shafts were failing in service, and the true factor of safety was less than one. The explanation lies in the fact that axle strength to be compared with the 13,000 psi operating stress should not have been the ultimate strength of the material (240,000 psi) but the fatigue strength corresponding to the surface finish of the shafts, the mode of loading to which the shaft was subjected, etc. When the ultimate strength was reduced by these derating factors, the resultant value was found to be 12,000 psi. This strength, when compared with the 13,000 psi stress, produced the realistic factor of safety of 0.9.

Examples such as this lead to the next phase in the relationship between stress and strength, namely, to the concepts of a significant stress and a significant strength. By significant stress is meant the actual stress imposed on the part, and it may include the effect of stress raisers, magnification due to impact loading, residual stresses, etc. By significant strength (generally, fatigue strength) is meant the <u>actual</u> strength of the part in its fabricated form under actual operating conditions. A rational approach to significant strength still employs ultimate strength as the basis. However, instead of an indiscriminate grouping of all the factors affecting the ultimate strength into one index, it attempts to evaluate quantitatively the effect of each individual factor pertaining to the part and the conditions under consideration. The result is a value which is strictly applicable to the part under consideration and to the set of loading conditions to which the part is subjected in service. The principal factors affecting strength and which must be considered in determining the significant strength are: life expectancy, type of loading (axial, bending, torsional, or a combination), size effect, surface finish, surface treatment, notch effects, mode of loading (static, completely reversed dynamic, or a combination).

These concepts of significant stress and significant strength represent a major step toward a more realistic prediction of reliability and, as such, they have been included in the present investigation. By themselves, however, they are not sufficient. This is because the prevailing practice is to use the mean values of the calculated strength and stress, ignoring the natural scatter that stresses and strengths may have.

The variability in these two factors results in the existence of a statistical distribution function of stress and strength (See Figure 2.1) and is the heart of the Interference Theory. Thus, for proper prediction of reliability, an estimate must be made of both the mean value and the dispersion characteristics of both the strength and stress.

The strength of the part, as all properties of non-homogeneous materials, varies from specimen to specimen, in view of the variation in hardness, surface finish, degree of stress concentration, etc. In our past investigation ("Reliability Prediction - Mechanical Stress/Strength Interference" by Charles Lipson, Narendra J. Sheth, and Ralph L. Disney, Final Report RADC-TR-66-710, March 1967, referred to in the present report as Reference 1) the problem of determining the variation in strength and subsequently its distribution function was resolved by a graphical method. Among the several possible distribution functions considered, only the Weibull distribution was used because of its wide use and the difficulty of handling other distributions by a graphical method. In the present investigation a computer approach was developed by which the determination of the distribution functions of strength became considerably less difficult. (This is discussed in Section 6.) Consequently, several distribution functions were tried. These were: Weibull, Largest Extreme Value, Smallest Extreme Value, Logistic and Normal. The reasons for selection of these particular distributions are given in Section 6.3. It was later found that the Logistic Distribution had somewhat the same characteristics as the Normal Distribution and, therefore it was not followed any further. The computer printed the degree of fit and the parameters for all of the above distributions for a given set of strength data. The best fitting distributions and their parameters were then chosen, and they are presented in a tabular form in Appendix 1 for various materials and conditions studied. The representative ones were then plotted in order to determine the effect of various conditions on the strength of various materials. In order to put the information on the same consistent basis, all the data were expressed in terms of the same distribution (Normal) and the plots were made by expressing the means (μ) and standard deviations (σ) as a function of life (See Section 6). The reasons for the selection of the Normal Distribution for these graphs are given in Section 6.

As is the case of strength, the operating stresses vary too. These stresses vary from time to time in a particular part, from part to part in a particular design, and from environment to environment. Therefore, both the mean value and the dispersion characteristics of stress and strength must be determined.

Once the parameters of the strength and stress distributions are found, percent interference and thus probability of failure can be determined

from the interference area (shaded area in Figure 2.1). Means of computing these interferences represent one of the principal objectives of the present investigation.

SECTION 2 INTERFERENCE THEORY

Suppose there are two barrels containing slips of paper, each having a number printed on it. The numbers in barrel Y are distributed according to distribution Y, as in Figure 2.1, and the numbers in barrel X are distributed according to distribution X. If, at random, slips of paper from each barrel are selected and paired, they may be classified into successes and failures. A success is constituted by a strength value exceeding a stress value, as for example, when $x_1 > y_1$. Failure will occur if $x_2 < y_2$ as shown. It will be noted that, although the shaded area is a measure of interference, it is not interference itself: a pair of points x_3 and y_3, although in the shaded area, will not produce failure. By continued pairing of stresses and strengths at random, pairs will be found where the stress will exceed the strength. By continued experimentation a good estimate of the probability of interference can be found.

2.1 TWO NORMAL DISTRIBUTIONS

From an exhaustive survey of literature made during the past investigation(1)*, it was found that most studies have assumed both the stress and the strength distributions to be normal. This is a natural assumption to make in order to solve a practical problem, as no work was found dealing with an analytical expression for the interference of two non-normal distributions.

When the stress and strength distributions are assumed to be normal, the probability of interference can be determined from the equation(2):

$$z = \frac{|\mu_y - \mu_x|}{\sqrt{\sigma_x^2 + \sigma_y^2}} \tag{2,1}$$

where μ_y = mean stress

μ_x = mean strength

σ_x^2 = strength variance

σ_y^2 = stress variance

z = standardized normal variate determined from standard tables (See Table 2.1)

Thus, if the average stress is 30 ksi with a standard deviation of 3 ksi and the average strength is 50 ksi with standard deviation of 10 ksi, $z = 1.91$ and from Table 2.1 α, which represents interference, is found to be .0281. Thus, the percent interference (the probability of failure) is 2.81%.

---

* Numbers in parenthesis designate References listed on Page 149.

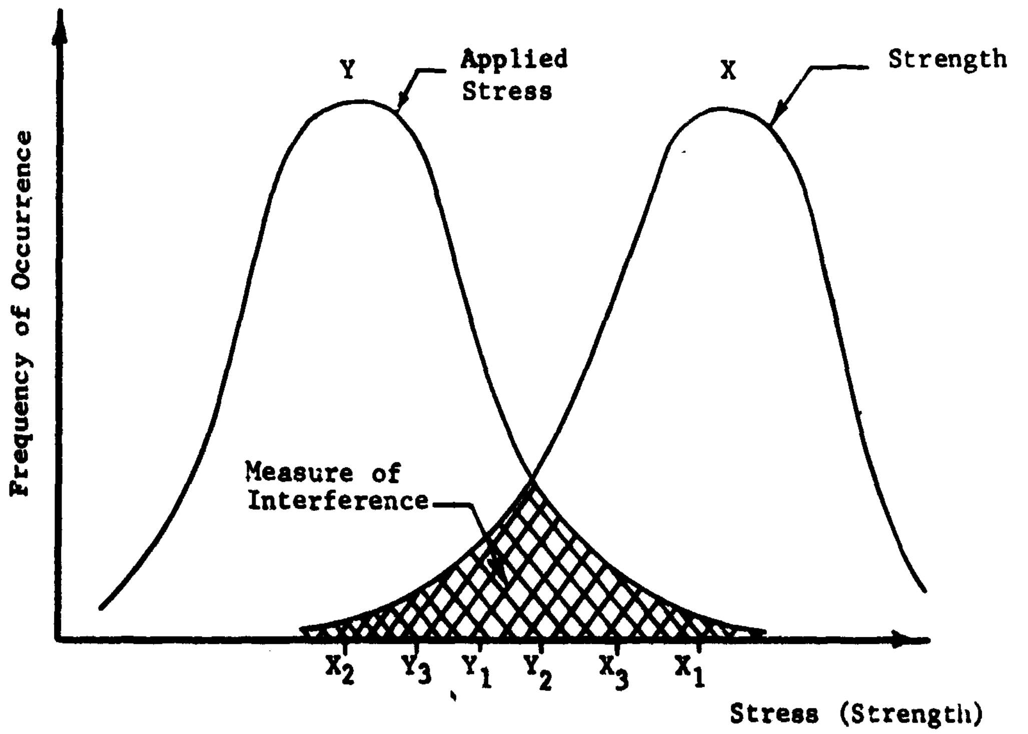


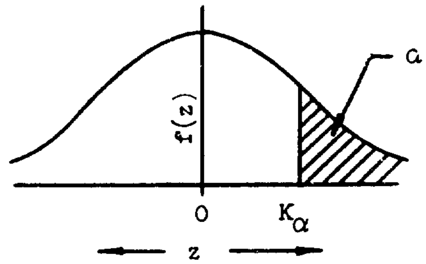
Figure 2.1 Interference of Stress and Strength Distributions

NORMAL DISTRIBUTION

Tabulation of the values of α versus K_α for the Standardized Normal Curve.

$$\alpha = P(z > K_\alpha) = \int_{K_\alpha}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} dz$$

= Area under the Standardized Normal Curve from $z = K_\alpha$ to $z = \infty$



K_α	.00	.01	.02	.C3	.04	.05	.06	.07	.08	.09
0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1011
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.C951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.00990	.00964	.00939	.00914	.00889	.00866	.00842
2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139

Table 11 Normal Distribution(2)

In practical applications of the Interference Theory the following problem arises: both distributions under consideration extend to plus and minus infinity. It is apparent, therefore, that any two distributions will overlap and cause interference. This, of course, is erroneous because some distributions, such as strength, must have a finite lower bound of zero. In many situations the physical set-up and the sample size adjust for this lower bound. For example, suppose a part is designed so that the mean of the strength distribution is placed 6 σ away from the mean of the stress distribution, both distributions having standard deviation equal to σ. From Equation 2.1 it is found:

$$z = \frac{6\sigma}{\sqrt{2\sigma^2}} = 4.24$$

and the probability of interference comes out to be .00001. This means that only one part will fail in 100,000 parts produced. If actually only 50,000 parts are made, the physical problem has effectively truncated the distributions. However, the probability of failure of one part remains .00001. This means that, due to sample size, the extreme portions of these distributions are no longer important since the sample size is such that not even one failure can be expected.

For the ease of application of the Interference Theory for the case of two Normal distributions, a graph was constructed as shown in Figure 2.2. The example solved previously through Equation (2.1) now yields:

$$\frac{|\mu_1-\mu_2|}{\sigma_{min}} = \frac{50ksi-30ksi}{3ksi} = 6.67 \text{ and,}$$

$$\frac{\sigma_{max}}{\sigma_{min}} = \frac{10ksi}{3\ ksi} = 3.3$$

and the percent interference (the probability of failure) comes out approximately 3% as before.

2.2 CONSISTENCY OF TWO DISTRIBUTIONS

In the application of the Interference Theory, the following important point must be considered: the distribution of stress and the distribution of strength must be consistent with each other. In a fatigue test or in actual application in service, a single part has a single fatigue life for a given loading condition. Subsequent testing of additional parts under the same load will show a scatter in life leading to a life distribution. Through more extensive testing a strength distribution for a given life can be obtained, such as the distribution in Figure 2.1 (the method of obtaining a strength distribution from a life distribution is described in Section 6).

It follows then that, for a consistent development, the stress distribution must be of the same nature as the strength distribution. That is, it should represent the plot of the frequency of occurrence of an applied stress versus the applied stress. This is not the same as the stress distribution conventionally derived from the spectrum of loading acting on the part. The con-

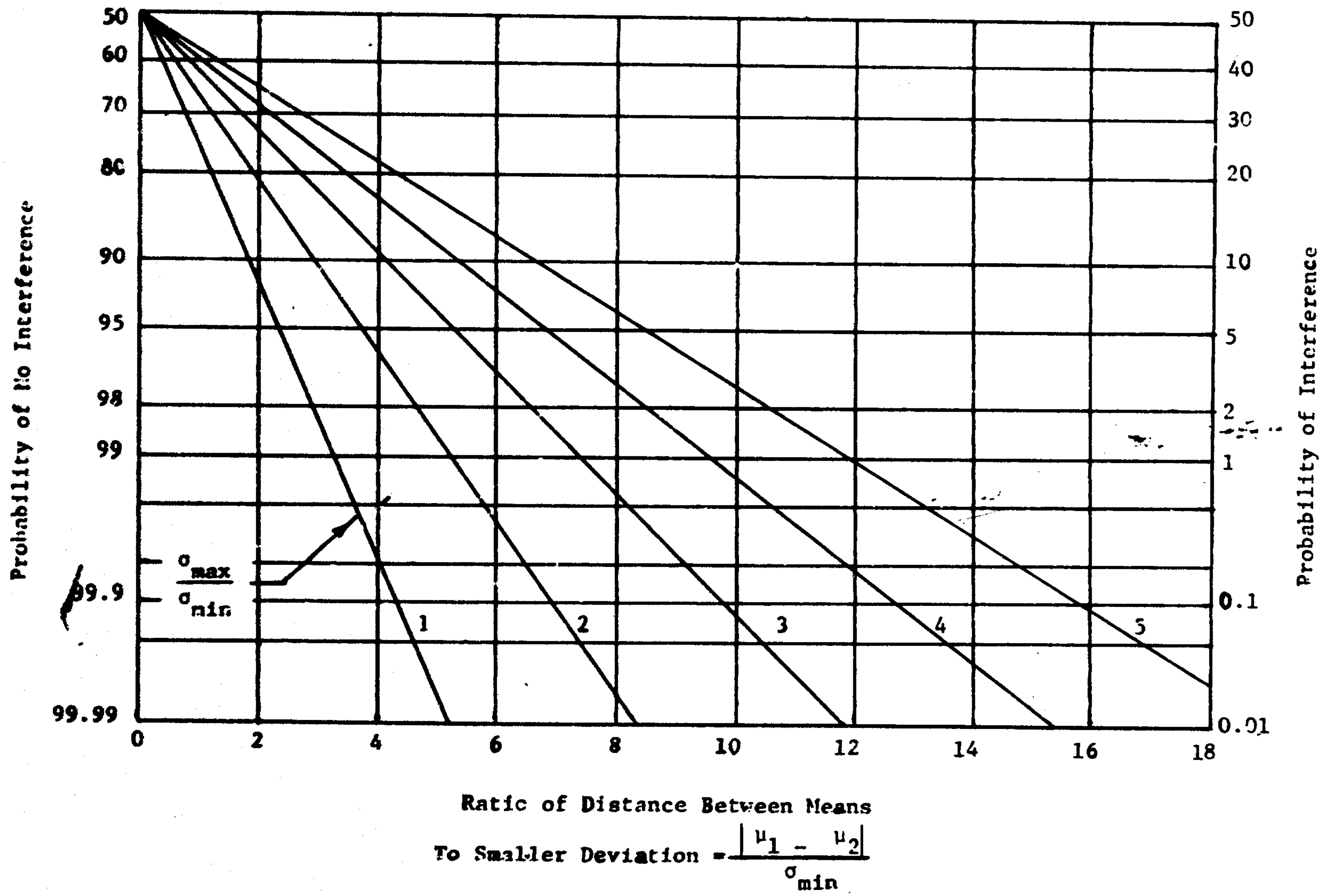


Figure 2.2 Probability of Interference of Two Normal Distributions.(3)

version of one to the other must be accomplished through the use of the equivalent stress (S_{equ}) and Miner's or Corten-Dolan's Rules. This is the method used in the present investigation, as described in Section 7.

2.3 NON-NORMAL DISTRIBUTIONS

So far the discussion has been limited to the cases when both the stress and strength distributions can be assumed to be normal. In cases when either one or both are not normal the problem is much more involved. For example, the intersection of a Normal and a Weibull distribution produces a distribution of an unknown origin.

In the past, problems such as this were solved largely through "brute force," by a method commonly referred to as the Monte-Carlo Technique. Essentially, the Monte-Carlo Technique consists of a sophisticated means of randomly selecting a sample from one distribution and comparing it with a random sample taken from a different distribution. This is accomplished with the aid of Tables of Random Numbers. The resultant paired data are plotted as a Cumulative Distribution Function on Normal, Weibull, etc. probability papers and the percent interference is read from the graph.

2.4 THE INTEGRAL METHOD

In the present investigation a Method of Integrals was used in preference to the Monte-Carlo Technique. This method involves determining, as an integral, the expression for the interference of the two distributions under consideration and establishing percent interference from this integral.

The advantages of the Integral Method are:

1. For some distributions the integrals have been already tabulated and percent interference can be read directly from the table.

2. In those cases where the integrals have not been already tabulated, they can be evaluated by Numerical Analysis as done in the present investigation.

3. The major shortcoming of the Monte-Carlo Technique is that it requires a very large sample size for any accuracy. This shortcoming is avoided when the Method of Integrals is used.

4. One of the objectives of the present study is to develop and evaluate an analytical expression for interference of any two distributions. Such an expression is possible when the Method of Integrals is used but not when the Monte-Carlo Technique is employed

SECTION 3 OBJECTIVES OF THE PRESENT STUDY

The objectives of the study described in this report were:

1. To refine and to reduce to practice the Stress/Strength Interference Theory technique for designing and predicting the quantitative reliability of mechanical parts and components fabricated from various non-ferrous materials under mechanical loading. Maximum use was to be made of empirical, practical engineering values as well as a sound theory.

2. To study the effect of such factors as type of loading, surface finish, temperature, heat treatment, stress concentration, surface treatment, manufacturing processes, environment, etc. on the statistical distribution of fatigue strength.

3. To determine, from the existing available empirical data, the distribution of the fatigue strength under the effect of each of the above factors.

4. To develop a computer approach [as contrasted with the graphical approach of our past investigation(1)] for determining the statistical distribution function of fatigue strength at a given life. This method has the advantage of high accuracy and time saving.

5. To develop the means of synthesizing the strength distribution function when such function is non-time variant, i.e. infinite life design, and when such function is time variant, i.e. finite life design.

6. To develop an analytical expression of the distribution of interference for the general case where the two interfering distributions are different. In the present investigation the distributions studied were:

Stress	Strength
Normal	Weibull
Normal	Largest Extreme Value
Normal	Smallest Extreme Value

SECTION 4 STUDY APPROACH

4.1 LITERATURE SEARCH

In the past investigation on ferrous materials[1], an exhaustive literature search was made to determine the State of the Art in the field of Reliability Prediction - Mechanical Stress/Strength Interference. Specific topics covered were: Interference Theory, Mathematical Tools as related to the Interference Theory, Monte-Carlo Technique, Reliability Prediction, Fatigue of Metals, Cumulative Damage, etc. As these topics were common to the past and the present investigations, it was not necessary to repeat them in the current study. Therefore, in the present project, no literature search was made.

4.2 THEORETICAL ANALYSIS

One of the objectives of this investigation was to develop and evaluate an analytical expression for the interference of two distributions. When the two distributions are Normal the interference can be simply expressed by a z-distribution, as described in Section 2. From an extensive survey of literature made in our past investigation, no work was found dealing with the analytical expression for interference when the two interfering distributions are not Normal. The purpose of this phase of the investigation, then, was to develop such expressions.

In the past investigation the analytical expressions and, hence, the tables of interference values, were developed by means of the Method of Integrals as discussed in Section 2.4 of Reference 1. These included:

Stress Distribution	Strength Distribution
Normal	Normal
Weibull	Weibull
Normal	Weibull

In the present investigation, data analysis (Section 6) revealed cases where fatigue strength data followed distributions other than Weibull or Normal. Hence it was necessary to develop tables of interference values for cases where stress distribution was Normal and strength distribution was Largest Extreme Value and, also, stress Normal and strength Smallest Extreme Value. This was done by evaluating the complex integrals expressing the distribution of interference. Numerical analysis was carried out (Appendix 3) using an IBM 360 computer to solve these integrals. Tables were then prepared for the interference values as a function of the distribution parameters (Appendix 2).

In addition, in the present investigation it was necessary to extend the scope of study for the case when the stress distribution is Normal and the strength distribution is Weibull. In the past investigation on ferrous materials[1], the study was limited to the cases where the stress-strength interference parameter, C

$$\left(C = \frac{\theta - X_o}{\sigma} = \frac{\text{strength index}}{\text{stress index}}\right),$$

was between 10 and 100. This was because the strength data on ferrous materials fell into this range of C values. In the present investigation on the strength data of non-ferrous materials, C values fell between 1.0 and 10.0 in many cases. Hence, it was necessary to extend the interference tables to include values of C between 1.0 and 10.0. Thus, tables of interference values were prepared to include the combinations:

Stress Distribution	Strength Distribution
Normal	Weibull (Extended)
Normal	Largest Extreme Value
Normal	Smallest Extreme Value

These tables are given in Appendix 2.

4.3 EMPIRICAL DATA

The tables of interference values are the heart of the Interference Theory as applied to engineering practice. Once the stress distribution and strength distribution parameters are known, the percent interference, and thus the probability of failure, can be read directly from these tables (for the procedure see Section 9 and for the tables see Appendix 2).

Over 250 articles from literature and other sources were examined in the past investigation, and practically no data were found concerning the statistical distribution of stress. In the present investigation some further work was done in this area, but no additional information was found. The only data located referred to spectrum of loads or stresses, which, as pointed out in Section 7, does not represent the stress distribution required for the Interference Theory. Interference Tables, therefore, were constructed so that, for given dispersion characteristics of stresses, a percent interference can be found. The range of these characteristics chosen here and corresponding to engineering practice are (if the stress distribution is Normal):

$$.01 \le \frac{\sigma}{\mu} \le .10$$

To determine the distribution of strength it was necessary to collect a great deal of data in order to arrive at a meaningful distribution. To systematize the effort of collecting data, a format was prepared which included the factors which are known to affect the final distribution of strength. An attempt was made to collect data in different areas in order to determine the effect of such factors as type of loading, size, processes, surface conditions, heat treatment, surface environment, temperature, surface treatment, stress concentration, etc.

The Mechanical Properties Data Center in Traverse City, Michigan, was found to be a very useful source of information for the fatigue strength data. They have been very cooperative in providing the necessary information. An exhaustive collection of data on the fatigue strength of non-ferrous materials was made from the Mechanical Properties Data Center. These data were then

systematized, evaluated in terms of the distribution parameters (Section 6), tabulated (Appendix 1), and the representative ones plotted (Section 6).

4.4 FACTORS AFFECTING THE STATISTICAL DISTRIBUTION OF FATIGUE STRENGTH

Since fatigue strength represents the major interest in the engineering applications of the Interference Theory, this problem was studied in some detail. The statistical distribution of the fatigue strength of a mechanical component is a function of a number of factors, such as type of loading, surface finish, stress concentration, heat treatment, temperature, environment, size of specimen, frequency of loading, surface treatment, manufacturing processes, grain size, impurities, and time. Each shows variability which is characterized by some form of a distribution. The effects of these factors on the statistical distribution of strength were studied in the present investigation.

Fatigue strength can be defined as the maximum stress that can be sustained for a specified number of cycles without failure, the stress being completely reversed within each cycle. In the case of steels, a component is said to have finite fatigue strength if it fails between 10^3 and 10^6 or 10^7 cycles due to a given magnitude of cyclic load. For non-ferrous materials this is generally extended to 5×10^8 cycles. In the present investigation the data were extrapolated to 10^8 cycles.

Type of Loading: The three major types of fluctuating load encountered in designing parts are axial, bending, and torsion. Experimentally determined values of the ratio of average fatigue strength for axial loading as compared to bending load were reported in literature as ranging generally from 0.75 to 1.0.[4,5] Although a great deal of work has been done to obtain precise values for this ratio, no detailed study has ever been made as to the statistical aspects of these strengths. Investigations have been conducted to find statistical distributions (Normal, Exponential, Weibull, etc.) of fatigue strength tested under a <u>given</u> type of loading, such as bending. No work was done to determine the effect on the distribution if the loads were other than bending. In the present investigation, an attempt was made to study the effect of different loads on the statistical distribution of the fatigue strength. The statistical parameters of the distribution for various materials under different loads were determined, tabulated according to materials (Appendix 1), and plotted in Section 6.

Surface Finish: The surface finish of a part does affect its endurance strength. Hence, the condition of finish should be taken into account when the design is based on fatigue. Surfaces which have an effect on the significant strength can be classified into five broad categories: polished, ground, machined, hot-rolled, and as-forged. The worse the surface condition the lower will be the mean fatigue strength but the higher will be the scatter. As a result, the degree of interference is likely to be pronouncedly affected by the type of surface finish imparted to the member. Different surface effects were studied in the present investigation and the fatigue strength parameters were tabulated (Appendix 1) and plotted in Section 6.

Stress Concentration: A notch or a stress raiser in a part subjected to fatigue loading can be regarded as a factor causing a local increase in stress or a reduction in strength. For example, a notch with a stress concentration factor of 2 can be thought of as doubling the stress or as halving the strength. In the present investigation this factor was taken as a strength reduction factor.

If all parts were made of materials which are completely homogeneous and have perfectly polished surface finishes, the effect of a notch would be to increase the stress by the factor K_t. Since actual materials are not perfectly homogeneous and actual surfaces are seldom perfectly polished, there exist internal and surface stress raisers. For this reason, the addition of a notch to a part, already having stress concentration due to geometry, generally produces a smaller effect than would be predicted from the theoretical stress concentration factor, K_t. The extent to which a notch reduces the endurance limit of a part is referred to as the fatigue stress concentration factor, or the fatigue strength reduction factor, and is designated by the symbol K_f. This is defined as:(6)

$$K_f = \frac{\text{endurance limit of specimen without the notch}}{\text{endurance limit of specimen with the notch}}$$

In this study, an attempt was made to determine the effect of stress concentration on the statistical scatter of the fatigue strength. More specifically, the objective was to find out whether this factor changes the mean strength only, whether it has an effect on the standard deviation, or whether it completely changes the nature of the distribution itself. The data were collected for various materials, various stress concentrations, and at different temperatures. Changes in the parameters of the statistical distribution of the strength due to the effect of stress concentration for different materials at various testing temperatures are tabulated in Appendix 1 and plotted in Section 6.

Heat Treatment: Different heat treatments such as annealing, solution heat treating, normalizing, quenching, tempering, aging, etc., can be imparted to materials to change their mechanical properties. Heat treatment may change the average fatigue strength but also the statistical scatter. Pertinent parameters are tabulated in Appendix 1 and plotted in Section 6.

Temperature: In a similar manner the effect of temperature on the statistical scatter of fatigue strength is shown in Appendix 1 and Section 6.

Environment: The effect of environment on the fatigue strength was confined in this investigation to the corrosive environment since most of the empirical strength data was in this area. It is known that a corrosive environment has a significant effect on the fatigue strength, particularly at a higher life. The statistical distribution parameters for various non-ferrous materials under different corrosive environments were determined, tabulated according to materials (Appendix 1), and plotted (Section 6).

Other Factors: In the present study it was observed that size and frequency of loading do not have any consistent effect on the distribution of the fatigue strength, whereas surface treatment, manufacturing processes, and impurities do exhibit consistent effects. The reason is that the latter may change the microscopic structure which, in turn, is related to strength. The statistical distribution parameters for various non-ferrous materials under the above conditions were determined, tabulated (Appendix 1) and plotted (Section 6).

4.5 COMPUTER ANALYSIS OF STRENGTH DATA

Data collected during this phase of the investigation were organized and systematized according to materials and conditions. A computer approach was developed to analyze these data (Section 6). In the past investigation using the graphical approach, only the Weibull distribution was used in the data analysis for the reasons discussed in Reference 1. In the present investigation, with the aid of the computer, other distributions besides Weibull, such as Largest Extreme Value, Smallest Extreme Value, and Normal, were tried. The reasons for the selection of these particular distributions are given in Section 6.3. The best fitting distribution and its parameters were determined for various materials and conditions and these are tabulated according to materials in Appendix 1.

SECTION 5 ANALYTICAL EXPRESSIONS FOR INTERFERENCE

5.1 INTRODUCTION

5.1.1 Interference Probabilities

In interference theory one supposes that the strength of a manufactured part is not known with certainty prior to performing some test on it and that the stress induced by a load is not known with certainty prior to actually loading the part. Thus, for example, one does not know with certainty that the strength of a part is exactly 50 ksi. He may know that the part cannot have a strength greater than 58 ksi or less than 40 ksi. Or he may know that the average strength that has been obtained in previous tests on these parts is 49 ksi. He may have some measure of how dispersed the strength measures are around this average strength. The point, of course, is that this type of knowledge is quite different from knowing precisely what the strength is prior to testing. For a multiplicity of reasons, strengths of seemingly identical parts are not exactly the same, and precisely what strength a part will have cannot be known until some type of strength test is performed. In the theory of probability one says that the strength of a part is a random variable. Certainly the same type of reasoning applies to the stress. Thus for a mathematical theory of interference one starts with the idea that strength is a random variable, say X, and stress is a random variable, Y.

In describing the properties of random variables, since their values are not known exactly, one supposes that, associated with every set of values that the random variable can take, there is a real number called the probability that the random variable takes values in the set. These probabilities are non-negative real numbers, they are all less than 1 and in the sense given below they "sum" to 1.

If x is any real number then there is a probability that the random variable takes some value less than or equal to x. Symbolically,

$$Pr(X \leq x)$$

is a number such that $0 \leq Pr(X \leq x) \leq 1$. Surely (i.e. with probability 1) $X \leq \infty$ so that

$$Pr(X \leq \infty) = 1 ,$$

and

$$Pr(-\infty > X) = 0.$$

Clearly $Pr(X \leq x)$ depends on the real number x. Consequently one defines a <u>probability distribution function</u>, F(x), by the relation

$$F(x) = Pr(X \leq x).$$

One sees immediately that

$$0 \leq F(x) \leq 1,$$
$$F(-\infty) = 0$$
$$F(\infty) = 1$$

and that $F(x)$ is a non-decreasing function.

In most engineering applications $F(x)$ has a derivative for every value of x, and one defines the probability density function, $f(x)$, by

$$f(x) = \frac{dF(x)}{dx} \quad .$$

One takes $$f(x)dx = Pr(x < X \leq x + dx).$$

(i.e. the probability density function multiplied by dx is the probability that X takes values in the neighborhood of x.) Since

$$f(x)dx = dF(x) \; ,$$

one has

$$\int_{-\infty}^{\infty} f(x)dx = \int_{-\infty}^{\infty} dF(x) = F(x) \Big|_{-\infty}^{\infty} = 1$$

the probabilities given by f(x)dx "sum" to 1.

In the mathematical theory of interference one assumes that the probability density function for the random variables X(strength) and Y (stress) are known. Sections 6 and 7 following show how these functions can be found from engineering data. Thus the "givens" of the mathematical theory of interference use the random variables X and Y, the set of values that they each can take (usually the non-negative real line), and the probability density or distribution function $F(x)$ [or $f(x)$] and $G(y)$ [or $g(y)$].

The problem to which interference theory addresses itself is that of finding the probability of failure. Failure is said to occur whenever the stress exceeds strength. Thus from the known probabilities for the X and Y random variables one wishes to find

$$Pr(Y \geq X) \; ,$$

which is the probability that stress exceeds strength or the probability of failure.

5.1.2 Calculation of Probabilities of Failure

There are two useful ways of determining the probability of failure from the known properties of X and Y.

(a) Since one wishes to find $Pr(Y \geq X)$ it is convenient in some cases (e.g. when stress and strength are normally distributed) to define a new random variable, Z, by the relation

$$Z = X - Y .$$

Then if one can find the probability density function of Z, h(z), the probability of failure will be simply the probability that $z \leq 0$. In terms of h(z) this is found by

$$Pr(\text{failure}) = \int_{-\infty}^{0} h(z)dz.$$

The problem in general is then to find h(z) from the known probability density functions f(x), g(y). A complete discussion of this method and its applications is found in Section A-3.2 of Reference [1].

In the important special case in which both stress and strength are normally distributed random variables it is well known that Z is also normally distributed with parameters.

$$\mu_Z = \mu_X - \mu_Y$$

and

$$\sigma_Z^2 = \sigma_X^2 + \sigma_Y^2$$

Consequently the probability of failure can be found directly from tables of the normal curve areas. One wants the area from $-\infty$ to 0 from these tables. A complete discussion of how to do this is given in Section 2.

(b) For most applications method (a) above is unnecessarily complex because one must first find the entire density function of the random variable Z before finding the probability of failure. Since the random variable Z is of no practical value for $Z < 0$, the approach in part (a) is unduly long. The methods described in this section are more direct and, from our experience, more useful in general.

One can derive the probability of failure as follows. Suppose we superimpose the stress and strength density function on the same graph as shown in Figure 5.1.

Although Y is a random variable, let us fix attention on a particular, small interval that Y can take values in. Let us fix $y < Y \leq y + dy$. Then let us find the probability that the random variable X takes values less than this fixed Y. One can show that this probability is

$$Pr(X \leq y \mid y < Y \leq y + dy) = \int_{0}^{y} f(x)dx .$$

The left hand side of this expression is called a <u>conditional probability</u>. It is the probability that the random variable X takes values less than the real number y when it is known ("given that") the random variable Y is "nearly" y.

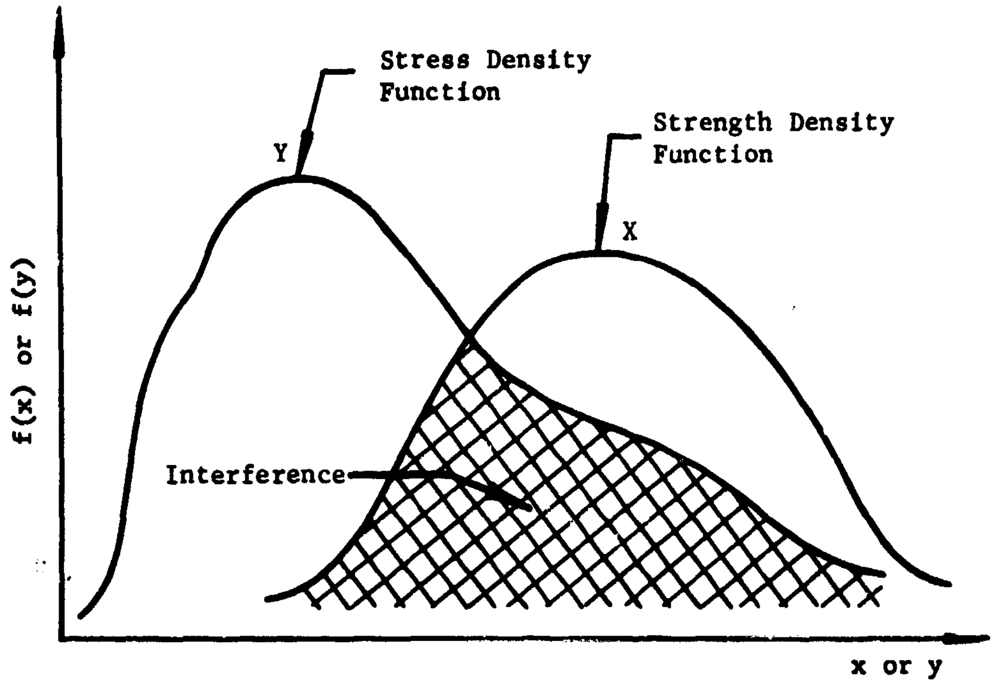


Figure 5.1 Interference of Stress and Strength Distributions

By the definition of f(x), this probability is obviously the same as the right hand side of the expression. If now we multiply this conditional probability by

$$\Pr(y < Y \leq y + dy) = g(y)dy ,$$

we obtain the joint probability that $X \leq y$ and $y < Y \leq y + dy$ which symbolically is

$$\Pr(X \leq y \mid y < Y \leq y + dy) \Pr(y < Y \leq y + dy)$$

$$= \Pr(X \leq y;\ y < Y \leq y + dy) .$$

This probability is given by the integral

$$\int_0^y f(x)dx \quad g(y)dy .$$

From the joint probability one obtains the probability of failure by:

$$\Pr(\text{failure}) = \int_0^\infty \int_0^y f(x)\ g(y)\ dx\ dy .$$

Thus this double integral gives the probability of failure directly.

If one recalls the relation between f(x) and F(x), it is clear that the double integral is easily reduced to the single integral

$$\Pr(\text{failure}) = \int_0^\infty F(y)\ g(y)\ dy .$$

If F(x) is easily obtainable then this expression is easier to work with than the double integral. For example, one knows that for a strength with a Weibull probability density function the probability distribution function F(x) is given by

$$F(x) = 1 - e^{-\left|\frac{x-x_o}{\theta_x-x_o}\right|^{b_x}}$$

In these cases the probability of failure is then given by

$$\Pr(\text{failure}) = \int_0^\infty \left(1-e^{-\left|\frac{y-x_o}{\theta_x-x_o}\right|^{b_x}}\right) g(y)\ dy$$

$$= 1 - \int_0^\infty e^{-\left|\frac{y-x_o}{\theta_x-x_o}\right|^{b_x}} g(y)\ dy .$$

The latter expression follows because

$$\int_0^\infty g(y)dy = 1$$

if the random variable Y takes only positive values which is the usual case in interference theory.

5.1.3 Interference Tables, Appendix 2

In Section 5.1.2 it was shown that the probability of failure could be expressed as an integral involving the known probability density or distribution functions. In certain cases this integral can be evaluated in closed form (e.g. when $f(x)$ and $g(y)$ are both exponential functions). In some cases this integral can be evaluated in terms of other well known and tabulated functions (e.g. when $f(x)$ and $g(y)$ are both gamma functions or when $f(x)$ and $g(y)$ are both normal functions). In general it is not to be expected that the integral for the probability of failure can be evaluated in closed form or in a form involving other well known functions. (e.g. when $f(x)$ and $g(y)$ are both Weibull functions or when $f(x)$ is a Weibull function and $g(y)$ is a normal function.) In those cases one must resort to numerical evaluation of the integral.

Since the integrals giving the probability of failure cannot be expressed in terms of well known functions, in general, we have evaluated the integral numerically. Tables of the probability of failure are given in Section A-2 of [1]. A full discussion of the numerical methods used and the errors of approximation appropriate to the tables are given in Section A-4 of [1].

Additionally, one is interested in the case in which the strength distribution is of the form

$$1 - e^{-e^{\beta(x-M)}} \qquad \text{when } \beta > 0, \quad -\infty \le x \le +\infty ,$$

called the <u>Smallest Extreme Value probability distribution function.</u> One is also interested in the case in which strength is distributed as

$$e^{-e^{-\beta(x-M)}} \qquad \text{when } \beta > 0, \quad -\infty \le x \le +\infty ,$$

which is called the <u>Largest Extreme Value probability distribution function</u>.

Section A-2.2 gives the probability of failure for the case in which strength is Weibull distributed and stress is normally distributed.

Section A-2.5 gives the probability of failure for the case in which strength is distributed with the Smallest Extreme Value distribution function and stress is normally distributed.

Section A-2.4 gives the probability of failure for the case in which strength is distributed with the Largest Extreme Value distribution function and stress is normally distributed.

5.2 USE OF INTERFERENCE TABLES IN APPENDIX 2

5.2.1 Parameters for the Weibull Distributed Strength, Normal Distributed Stress

The form for the integral involved in finding the probability of failure when the strength is Weibull distributed and the stress is normally distributed is given in Section A-3.3.5 of [1]. Tables of these probabilities are given in Section A-2.1 of [1]. A discussion of the numerical analysis, error and accuracy of the tables is given in Section A-4.1.7 of [1].

The form of the distribution of the strength has been given in Section 5.2.1 of [1].

In the past investigation, extensive tables of interference values (Section A-2.1.2 of [1]) were prepared for the parameter C (as defined below) equal to 10 or above. In the present investigation on non-ferrous materials, the values of parameter C much lower than 10 were needed. Hence, the Tables A-2.1.2 of [1] were extended to cover the range of $1 \leq C < 10$. Therefore, the Tables of this report list probabilities of failure for

$$B(x) = 1, 1.2, 1.3, \ldots 3.2$$

$$C = 1., 2., \ldots 10.$$

$$A = 0, .2, .4, \ldots 2.8 \text{ and } -.2 \text{ to } -10.0$$

where

b_x = the slope of the strength distribution. In the tables this is called B(x).

$(\theta_x - x_o)/\sigma$ = the ratio of the difference of the characteristic strength and the truncation parameter (or lower bound of strength) to the standard deviation of the stress. In the tables this is called C for typographical simplicity.

$(X_o - \mu)/\sigma$ = the difference between the strength truncation parameter and the mean stress divided by the standard deviation of the stress. In the tables this is called A for simplicity.

The values in the body of the table are the probabilities of failure for the parameters given at the heading of the tables. From the discussion given in Section A-4.1.7 of [1] these probabilities are correct to $\pm 5 \times 10^{-5}$.

5.2.2 Parameters for the Smallest Extreme Value Distributed Strength, Normal Distributed Stress

In this case it has been found that the integral giving the probability of failure can be expressed in terms of two parameters which are denoted by

α and γ. In the tables these parameters are given by

$\gamma = \beta(\mu - M)$ = the difference in the location parameter (μ) for the normally distributed stress and the mode (M) for the Smallest Extreme Value distributed strength. This difference is multiplied by β, the slope parameter of the extreme value distribution.

$\alpha = \beta\sigma$ = the product of the standard deviation of the Normal distribution for the stress variable and the slope parameter for the Smallest Extreme Value distributed strength.

The tables give the probability of failure for

α: .001, .005, .025, .05, .075, and .1 to 3.0 in steps of 0.1 and 3.5 to 10 in steps of 0.5.

γ: 0 to -40 in steps of 1.0

The values in the tables give the probability of failure corresponding to the values of α,γ given at the column and row heads. These probabilities are correct to within $\pm 2 \times 10^{-4}$ according to the discussion given in Section A-3.

5.2.3 Parameters for the Largest Extreme Value Distributed Strength, Normal Distributed Stress

In this case, the integral expressing the probability of failure is almost identical to that in the previous case (Section 5.2.2). The definitions of the parameters α and γ are identical. The tables give probabilities of failure for the ranges of α and γ listed in Section 5.2.2. These probabilities are also correct to $\pm 2 \times 10^{-4}$ as discussed in Section A-3.

5.2.4 Use of the Tables, Explanation of Missing Values and Interpolation

Numerical examples of the use of the tables are given in Section 9. In general the user will enter the table with known parameters, for example, b_x, θ_x, x_o and the appropriate parameters for the stress distribution, and wish to find the probability of failure. This is a direct table look-up. In some design problems the user will have a given probability of failure to achieve and will know the general shape of the distribution of stress and strength appropriate to the material that he is using. The table will then give him the relative parameters (there may be many of these) to design for. It would be expected that a cost analysis would give the acceptable parameter values for each distribution. As long as the relative values are as given in the table, the probability of failure will be the same no matter what the values for each distribution are.

In the Weibull Strength-Normal Stress tables, the missing values within the ranges of the parameters used are nearly zero and hence have not been tabulated. When $A = (x_o - \mu)/\sigma > 3.5$, the probability of failure is less than 1×10^{-4} since the area under the normal curve from 3.5 to ∞ is less than 3×10^{-4}.

For the Normal-Extreme Value cases, the probabilities of failure are zero (to 4-places) whenever $\gamma < -39$ and $\alpha < 10$.

When $\alpha = \beta\sigma = 0$ (or $\sigma = 0$), then the stress distribution for either the Normal-Smallest Extreme Value or Normal-Largest Extreme Value case is a straight-line distribution, and the probabilities of failure can be computed as in Appendix 2. These formulas are repeated here since they give very good approximations for the probabilities even when $\alpha \neq 0$ but is small (say $\alpha < .001$).

For $\alpha = 0$:

$$\Pr\left[\text{failure}\right]_{\text{(Normal-Smallest)}} = 1 - e^{-e^{\gamma}}$$

$$\Pr\left[\text{failure}\right]_{\text{(Normal-Largest)}} = e^{-e^{-\gamma}} \qquad \text{where } \gamma = \beta(\mu - M)$$

It can be seen that the tables are non-linear for almost all values of the parameters. This can cause inaccuracies when the tables are interpolated. The absolute value of the interpolation error depends on which tables are interpolated. For precise values the user should use a higher order interpolation formula (as given in Section A-2.1) rather than linear interpolation. We have not explored the relative errors of interpolation closely. In those cases checked, the relative errors are small.

SECTION 6 STATISTICAL DISTRIBUTION OF FATIGUE STRENGTH BY COMPUTER APPROACH

Most fatigue testing involves subjecting specimens or parts to a fluctuating stress to failure and repeating this process at various stress levels. The data thus obtained, known as life data, are used to construct the conventional S-N diagram. In this case, the scatter obtained is the scatter in life at a given stress. In the present investigation the attention was focused on the nature of the scatter in fatigue strength at a given life. In the past investigation[1], where the study was made mainly on the ferrous materials, the problem of determining the scatter in the fatigue strength and, subsequently, its distribution function was resolved by a graphical method discussed in Reference 1. Among the several possible distribution functions that were considered, only the Weibull distribution was used because of its wide use and the difficulty of handling other distributions by a graphical method. In the present investigation on the non-ferrous materials a computer approach was developed by which the determination of the distribution functions of strength became considerably less difficult. Consequently, it was possible to try out such other distributions as Largest Extreme Value, Smallest Extreme Value, Logistic, and Normal besides the Weibull which was tried in the past investigation. The reasons for selection of these particular distributions are given in Section 6.3. The computer program was so developed that when the raw data (conventional S-N type data) were fed into this program, the computer printed the degree of fit and the parameters for all the above distributions for a given set of strength data. In the first part of this program the scatter in the life was converted into the scatter in the fatigue strength. In the second part, the distribution functions (Weibull, Normal, Logistic, Largest Extreme Value, and Smallest Extreme Value) were fitted to these strengths data simultaneously, and the one with the highest degree of fit was the best fitting distribution. The detailed discussion on this computer approach and the necessary statistical tools that were used in developing the approach are given in the following sections. The flow chart of the computer program used to determine the fatigue strength distribution is given in Appendix 4.

6.1 LEAST SQUARES METHOD OF FITTING A LINE TO S-N TYPE DATA

6.1.1 Method of Least Squares

The principle underlying the "best fit" of a line by the least squares method is that the sum of the squares of the deviations in the y-direction of the data points (X_i, Y_i) from the most probable line is minimum (See Figure 6.1). The equation of this line is:

$$Y = \alpha + \beta X \tag{6.1}$$

where α is intercept on Y-axis

and β is the slope of the line.

The parameters α and β are found from the following relationships[2]:

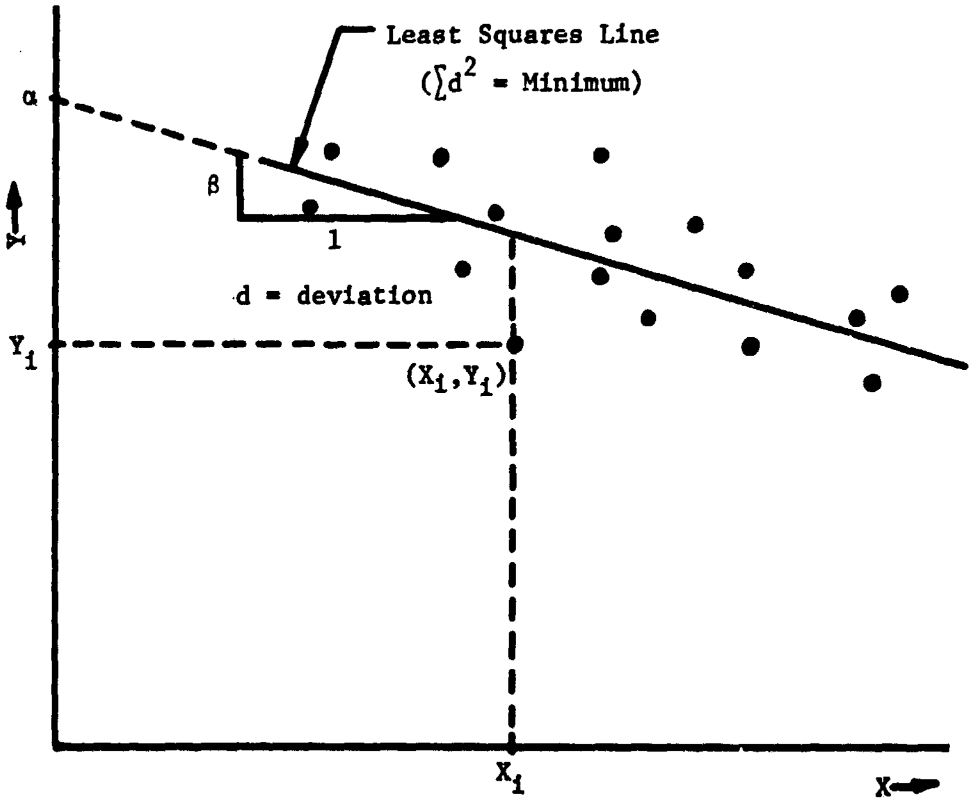


Figure 6.1 Least Squares Line

$$\beta = \frac{n \sum_{i=1}^{n} Y_i X_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{n \sum_{i=1}^{n} X_i^2 - \left[\sum_{i=1}^{n} X_i \right]^2} \tag{6.2}$$

$$\alpha = \frac{\sum_{i=1}^{n} Y_i - \beta \sum_{i=1}^{n} X_i}{n} \tag{6.3}$$

where n = the total number of points

X_i = abscissas of points

Y_i = ordinates of points

6.1.2 Application of Least Squares Method to S-N Data

When stress-life (S-N) data are plotted on a log-log paper or log (S) and log (N) are plotted on a Cartesian paper, an approximately straight line results. Hence, the S-N data are related by the equation:

$$\ln (S) = \alpha + \beta \ln (N)$$

When ln (S) and ln (N) are substituted for Y and X in the Equations (6.2) and (6.3), they reduce to:

$$\beta = \frac{n\left(\sum_{i=1}^{n} (\ln N_i)(\ln S_i)\right) - \left(\sum_{i=1}^{n} \ln N_i\right)\left(\sum_{i=1}^{n} \ln S_i\right)}{n\left(\sum_{i=1}^{n} (\ln N_i)^2\right) - \left(\sum_{i=1}^{n} \ln N_i{}^2\right)} \tag{6.4}$$

$$\alpha = \frac{\sum_{i=1}^{n} (\ln S_i) - \beta \sum_{i=1}^{n} \ln N_i}{n} \tag{6.5}$$

where α and β are the intercept and the slope of the S-N line (See Figure 6.2)

n = the total number of test points

N_i = the i^{th} life, corresponding to the i^{th} stress, S_i

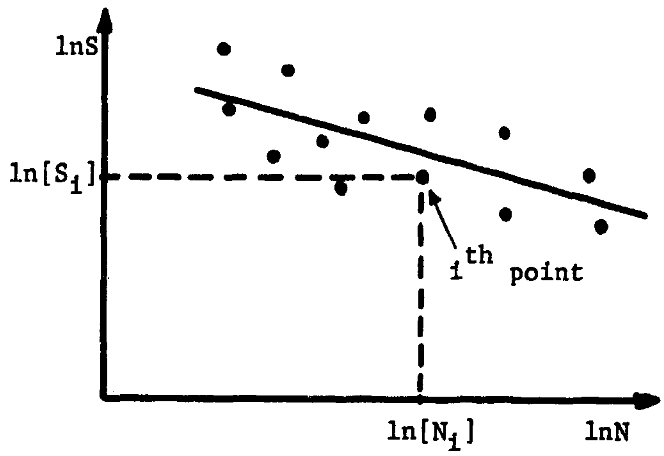


Figure 6.2 lnS - ln N Diagram

6.1.3 Correlation Coefficient

Correlation Coefficient (R) is an index of the goodness of fit of the least squares line to a set of data. In the previous section it was pointed out that a straight line can be fitted to a set of data with known coordinates, for example, ln (S) and ln (N). This section deals with a computation of correlation coefficient (R) which is a measure of the goodness of fit. The correlation coefficient is defined as:

$$R = (\beta)^2 \frac{S_x^2}{S_y^2} \qquad (6.6)$$

where β = the slope of the fitted line.

$$S_x^2 = \frac{n \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}{n\ (n-1)} \qquad \text{Sample variance of X (abscissas)} \qquad (6.7)$$

$$S_y^2 = \frac{n \sum_{i=1}^{n} Y_i^2 - \left(\sum_{i=1}^{n} Y_i\right)^2}{n\ (n-1)} \qquad \text{Sample variance of Y (ordinates)} \qquad (6.8)$$

If the correlation coefficient (R) is 1.0, every data point falls on the least square line and the data has the best fit. On the other hand, if the correlation coefficient (R) is equal to zero, all the data are around a circle and the data has very poor fit. (See Figure 6.3)

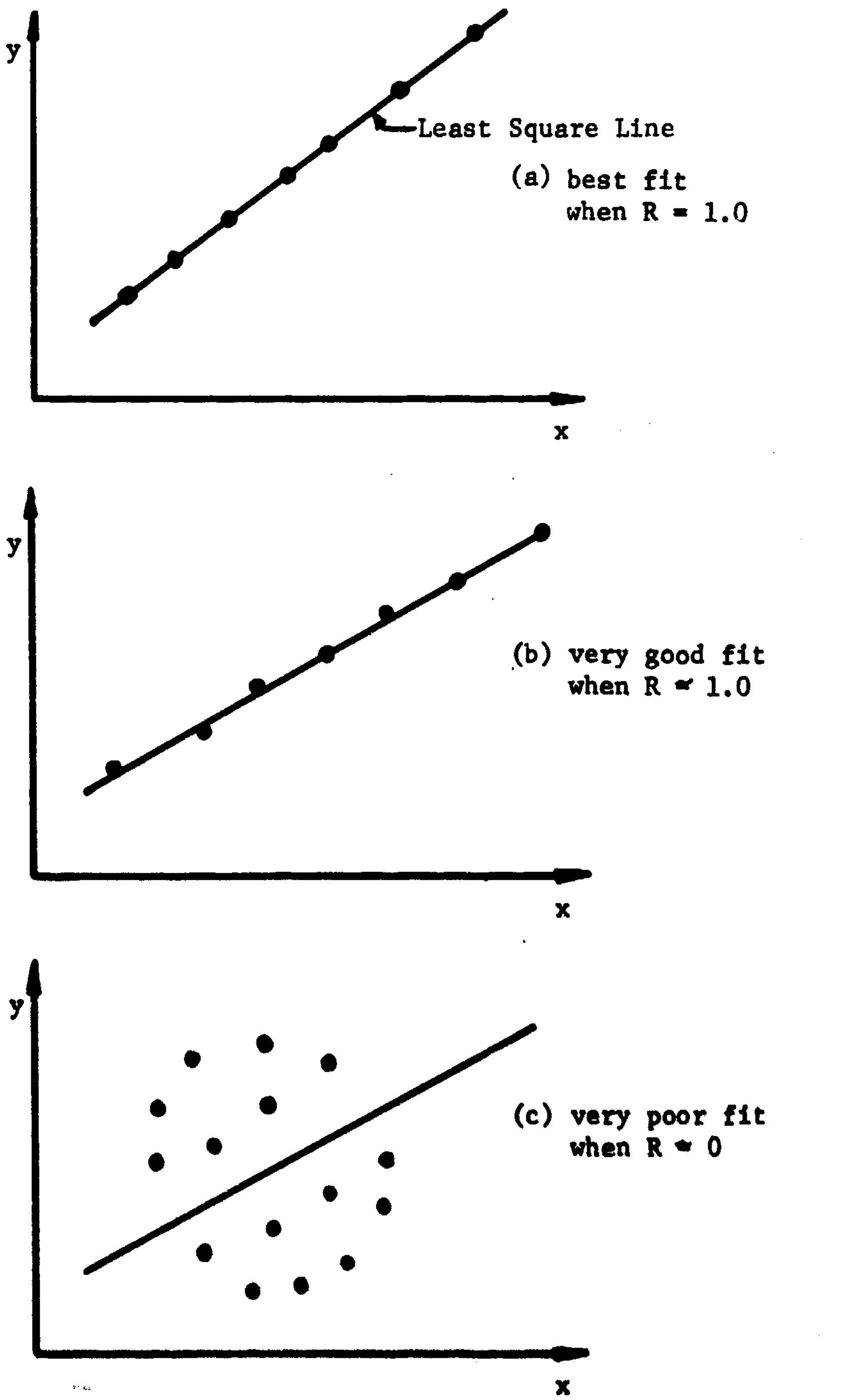


Figure 6.3 Goodness of Fit for Various Correlation Coefficients (R)

Five distributions (Weibull, Normal, Logistics, Largest Extreme Value, and Smallest Extreme Value) were fitted to each set of the fatigue strength data, and the values of the correlation coefficient (R) for each fitted distribution were computed from Equation (6.6). The distribution having the largest value of R was taken as the best fitting distribution.

6.2 CONVERSION OF LIFE DATA TO STRENGTH DATA

In the past investigation[1] on ferrous materials the conversion of life data to strength data was accomplished graphically where the data were plotted on the conventional S-N diagram and the least squares S-N curve was then fitted to the test points. Passing through each point an S-N curve parallel to the least squares curve was drawn. These made a set of parallel S-N lines. (See Figure 6.4). A vertical line was drawn at a given life, say N_1, intersecting the family of S-N curves. The points of intersection S_1, S_2, S_3 ... represent the scatter of the fatigue strength at the life N_1 (See Figure 6.4). Here, it was assumed that to each specimen of the population can be attributed an individual S-N curve, and that there exists for any population of specimens (at fixed test conditions) a family of non-intersecting S-N curves which can be determined with any desired accuracy, each curve corresponding to a given probability.

In the present investigation on non-ferrous materials, this basic assumption was held still true, and for the purpose of developing the computer approach, it was necessary to develop an analytical approach for the above graphical method. This is given in the following sections.

6.2.1 Computation of Parallel S-N Lines

The general form of the equation of the parallel S-N curves is:

$$\ln S = \alpha_i + \beta \ln N \tag{6.9}$$

where β is the slope of the lines as computed from Equation (6.4)

α_i is the intercept of the line passing through a given point (N_i, S_i)

and i is the subscript which takes values from 1 to n where n is the number of parallel lines

In order to determine the equation of each line, it was necessary to compute the corresponding values of α_i from the following equation:

$$\alpha_i = (\ln S_i) - \beta (\ln N_i) \; . \tag{6.10}$$

By substituting the values of S-N data, (S_1, N_1), (S_2, N_2), (S_3, N_3)..., in Equation (6.10), α_1, α_2, α_3... can be computed. Hence, using Equation (6.9), a set of equations for each parallel line was obtained.

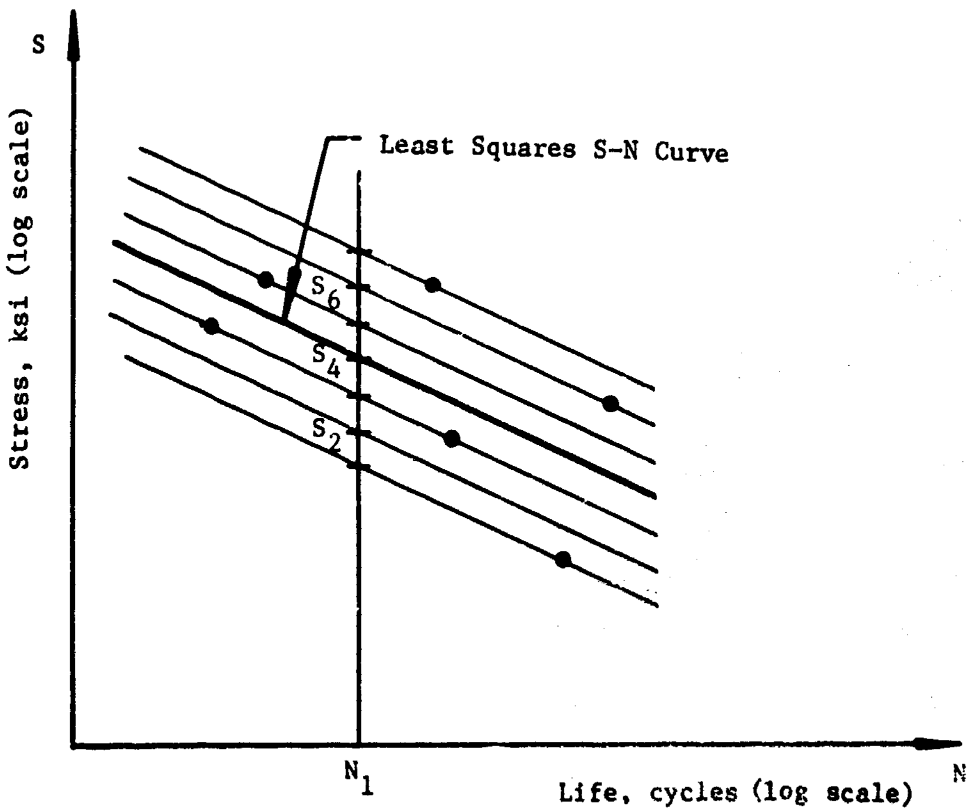


Figure 6.4 S-N Diagram for converting Life Data to Strength Data

$$\ln S = \alpha_1 + \beta \ln N$$

$$\ln S = \alpha_2 + \beta \ln N$$

$$\ln S = \alpha_3 + \beta \ln N \qquad (6.11)$$

6.2.2 Computation of the Scatter of Strength at a Given Life

A life, say N_1, was chosen at which the scatter of strength was desired. By substituting $\ln N_1$ in Equation (6.11), a set of values of $\ln S_1$, $\ln S_2$, $\ln S_3$ ..., were obtained. By taking antilog of these values, the scatter of fatigue strengths S_1, S_2, S_3 ... for the life N_1 was obtained. This was repeated for several values of life N_j, and the resulting scatters of fatigue strengths, S_{i_j}, were stored by computer for further analysis.

Median ranks(2) were then assigned to the scatter of the fatigue strength data, S_{i_j}, arranged in increasing order. The analytical expression for the median ranks that was used for the computer programming was(7):

$$\text{Median Rank} = \frac{j - .3}{n + .4}$$

where j = order number and

n = total number of data points.

6.3 DISTRIBUTION FUNCTIONS

The most common probability distributions that were found from literature for expressing the fatigue strengths are: Weibull, Largest Extreme Value, Smallest Extreme Value, Normal, and Logistic. These cover a considerable variety of distribution patterns. For example, Weibull distribution generates a wide variety of distributions by choosing different values of its parameters, X_0, θ, and b, (this is discussed in the following section). Extreme Value distribution (Largest and Smallest) takes care of some of the unexplainable phenomenon observed in connection with the fracturing of materials under the applied dynamic load where the puzzling question is: Why is the strength of a specimen considerably smaller or larger than its expected value? The reason for this difference in the values lies in the fact that there may exist flaws in the specimen that will weaken it. Normal distribution was used for the obvious reason that it can be justly called the most common and well known distribution. Logistic distribution, which has somewhat the same characteristics as the Normal distribution, was tried, but later it was found from the computer results that Normal fits the data just as well as Logistic. Hence, in those cases where Logistic fitted the data best, the Normal was used, instead, to express the fatigue strength. Besides, Normal distribution is widely used and is easier to understand for engineers with little statistical background. It is for these reasons that the discussion on the Logistic distribution does not appear in the following section. Other distributions are discussed below.

6.3.1 Weibull Distribution

The Weibull equation is a three parameter function. The general expression for the Weibull density function is:

$$p(x) = \frac{b}{\theta - X_o} \left(\frac{x-X_o}{\theta-X_o}\right)^{b-1} e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^{b}}, \qquad (6.12)$$

$$X_o \leq x \leq \infty$$

and the general expression for the cumulative distribution function is:

$$P(x) = 1 - e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^{b}}, \quad X_o \leq x \leq \infty \qquad (6.13)$$

where, as used in this study,

x is the independent variable (fatigue strength)

X_o is the lower bound of fatigue strength

θ is the characteristic fatigue strength, where 63.2% of the population have strengths less than or equal to this value(2)

b is the Weibull slope

6.3.2 Normal Distribution

Normal distribution is a two parameter function. The general expression for Normal density function is:

$$p(x) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}, \quad -\infty \leq x \leq +\infty \qquad (6.14)$$

where x is the independent variable (fatigue strength)

μ is the population mean

σ is the population standard deviation

By a simple transformation, this can be reduced to:

$$P(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} e^{-\frac{z^2}{2}} dz \qquad (6.15)$$

where z = standardized normal variate = $\frac{x-\mu}{\sigma}$

and P(y) = probability of $z \leq y$.

6.3.3 Extreme Value Distributions

Gumble[8] designed what is known as the Extreme Value Distribution which is generally used to estimate the tail-ends of the frequency distributions. This distribution determines the probability of occurrence of an event. Largest values or smallest values of an event can be estimated by Largest Extreme Value distribution or Smallest Extreme Value distribution respectively. The general expression for the density function is:

Largest Extreme Value (L.E.V.):

$$p(x) = \beta\, e^{-\beta(x-M) - e^{-\beta(x-M)}} \tag{6.16}$$

$$= \beta\, e^{-\beta(x-M)} \cdot e^{-e^{-\beta(x-M)}}, \quad -\infty \leq x \leq +\infty \tag{6.17}$$

Smallest Extreme Value (S.E.V.):

$$p(x) = \beta\, e^{+\beta(x-M) - e^{+\beta(x-M)}}$$

$$= \beta\, e^{+\beta(x-M)} \cdot e^{-e^{+\beta(x-M)}}, \quad -\infty \leq x \leq +\infty \tag{6.18}$$

The general expression for the cumulative distribution function is:

Largest Extreme Value (L.E.V.):

$$P = e^{-e^{-\beta(x-M)}} \tag{6.19}$$

Smallest Extreme Value (S.E.V.):

$$P = 1 - e^{-e^{+\beta(x-M)}} \tag{6.20}$$

where β = intensity function (slope)

M = Extreme Value (mode)

β and M are also called the extremal parameters. Comparison of characteristics of Extreme Value distribution with Normal distribution is given in Table 6.1 which is self-explanatory.

Characteristic	Largest Value	Smallest Value	Normal Variate
A. Distribution			
1. Cumulative probability function for reduced variate, Φ	$e^{-e^{-y}}$	$1-e^{-e^{y}}$	$\int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}t^2} dt$
2. Reduced variate ------------	$y=\alpha(x-u)$	$y=\alpha(x-u)$	$z=\frac{1}{\sigma}(x-\mu)$
3. Original variate, x, in terms of reduced variate ---	$x=u+y/\alpha$	$x=u+y/\alpha$	$x=\mu+\sigma z$
B. Reduced Variate y			
4. Moment generating function G(t) ----------------------	$\Gamma(1-t)$	$\Gamma(1+t)$	$e^{\frac{1}{2}t^2}$
5. Mode $\tilde{y}$ --------------------	0	0	$\tilde{z}=0$
6. Mean $\bar{y}$ --------------------	$\gamma=0.57722$	-0.57722	$\bar{z}=0$
7. Median $\breve{y}$ ------------------	-lglg2=0.36651	-0.36651	$\breve{z}=0$
8. Standard deviation σ -------	$\pi/\sqrt{6}=1.28255$	1.28255	1
9. Skewness β_1 ---------------	1.29857	-1.29857	0
10. Kurtosis β_2 ---------------	27/5	27/5	3
C. Deviates y_Φ Corresponding to Given Probability Points Φ			
11. $\Phi = .95$ -------------------	2.97020	1.09718	1.64485
12. $\Phi = .99$ -------------------	4.60015	1.52718	2.32635

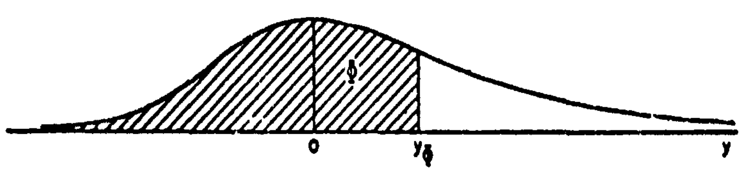
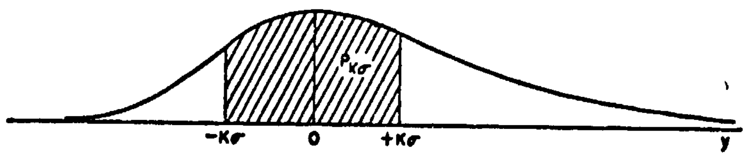


Table 6.1 Comparison of Characteristics of Extreme Value Distribution and Normal Distribution(8)

Characteristic	Largest Value	Smallest Value	Normal Variate

D. Area $P_{K\sigma}$ Included Within Mode = $K\sigma$



13. K=1; $P_{K\sigma}=\Phi(\sigma)-\Phi(-\sigma)$------------	0.73064	0.73064	0.68269
14. K=2; $P_{K\sigma}=\Phi(2\sigma)-\Phi(-2\sigma)$----------	0.92597	0.92597	0.95450
15. K=3; $P_{K\sigma}=\Phi(3\sigma)-\Phi(-3\sigma)$----------	0.97890	0.97890	0.99730
16. Variate y for which P_y=0.68269	1.14071	1.14071	1.00000
17. Variate for which P_y=0.95450--	3.06685	3.06685	2.00000

E. Original Variate, x

18. Mode $\tilde{x}$------------------------	u	$-u$	μ
19. Mean $\bar{x}$------------------------	$u+\gamma/\alpha$	$-u-\gamma/\alpha$	$\mu+\sigma\bar{z}=\mu$
20. Median $\breve{x}$----------------------	$u+0.36651/\alpha$	$-u-0.36651/\alpha$	$\mu+\sigma\breve{z}=\mu$
21. Standard deviation σ_x---------	$\frac{1}{\alpha}\cdot\sigma=\frac{1}{\alpha}\cdot\frac{\pi}{\sqrt{6}}$	$\frac{1}{\alpha}\cdot\sigma=\frac{1}{\alpha}\cdot\frac{\pi}{\sqrt{6}}$	$\sigma\cdot 1$

Table 6.1 (Continued) Comparison of Characteristics of Extreme Value Distribution and Normal Distribution(8)

6.4 THE LINEARIZING TRANSFORMATION EQUATIONS OF THE DISTRIBUTION FUNCTIONS

When x, the independent variable (in this case the fatigue strength), and P, the dependent variable (in this case the cumulative probability of the fatigue strength), are plotted on a Cartesian graph paper, the resultant plot is non-linear (sigmoidal or S-shaped plot) as shown in Figure 6.5.

Such a curve is difficult to work with. To fit this curve to a set of data it is necessary to use the curvilinear regression analysis. This analysis is quite involved as compared to the linear regression analysis which can be used to fit only the straight lines. Hence, if the non-linear function can somehow be transformed into a linear function, the linear regression analysis can be employed. This can be done by transforming the dependent (P) and independent (x) variables of the function to a new set of dependent [T(P)] and independent [G(x)] variables. This process is called the Linearizing Transformation. The functional relationships between the variables (independent and dependent) of the sigmoidal form of the distribution (Figure 6.5) and variables of the linear (Figure 6.6) form of the distribution are called the linearizing transformation equations. These are given as:

$X = G(x)$ = independent variable plotted on abscissa

$Y = T(P)$ = dependent variable plotted on ordinate

The linearizing transformation is used in many engineering applications. For example, in strength-life (S-N) diagrams with the ordinate and the abscissa having logarithm scale;

$Y = \ln S$

and $X = \ln N$ are the linearizing transformation equations where ln S and ln N are called the linear mode variables and S and N are the original variables. Or, in case of Weibull distribution, $\ln\ln \frac{1}{1-P(x)}$ and $\ln (x-X_0)$ are the linear mode variables where as P(x) and x are the original (or non-linear mode) variables. In the analysis of fatigue strength data, linearization transformation can be stated as:

$$Y = T(P) \tag{6.21}$$

$$X = G(x) \tag{6.22}$$

where T and G are the linearizing transformation equations relating original variables P and x to linear mode variable Y and X respectively. The functions G and T should be such that the inverse transform operation on them gives the original variables. These inverse transformation equations are:

$$P = T^{-1}\ (Y)$$

$$x = G^{-1}\ (X).$$

The inverse transformation equations are important for finding the parameters of original distribution functions. This will be discussed in the section that follows.

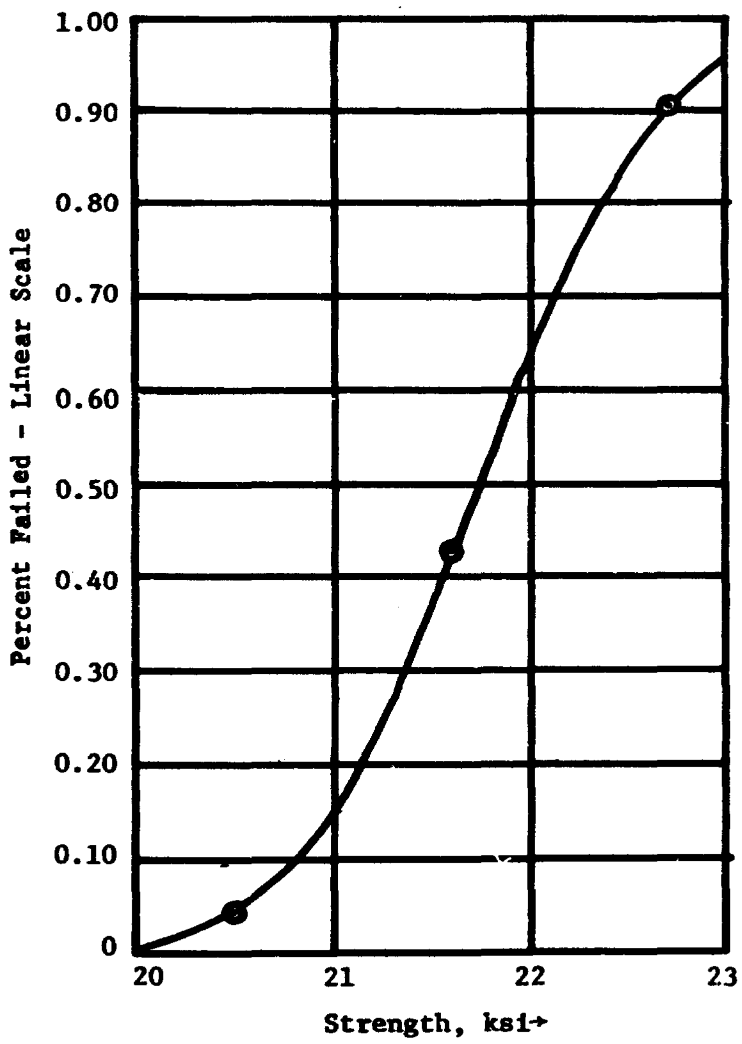


Figure 6.5 Sigmoidal Mode of Cumulative Distribution Function

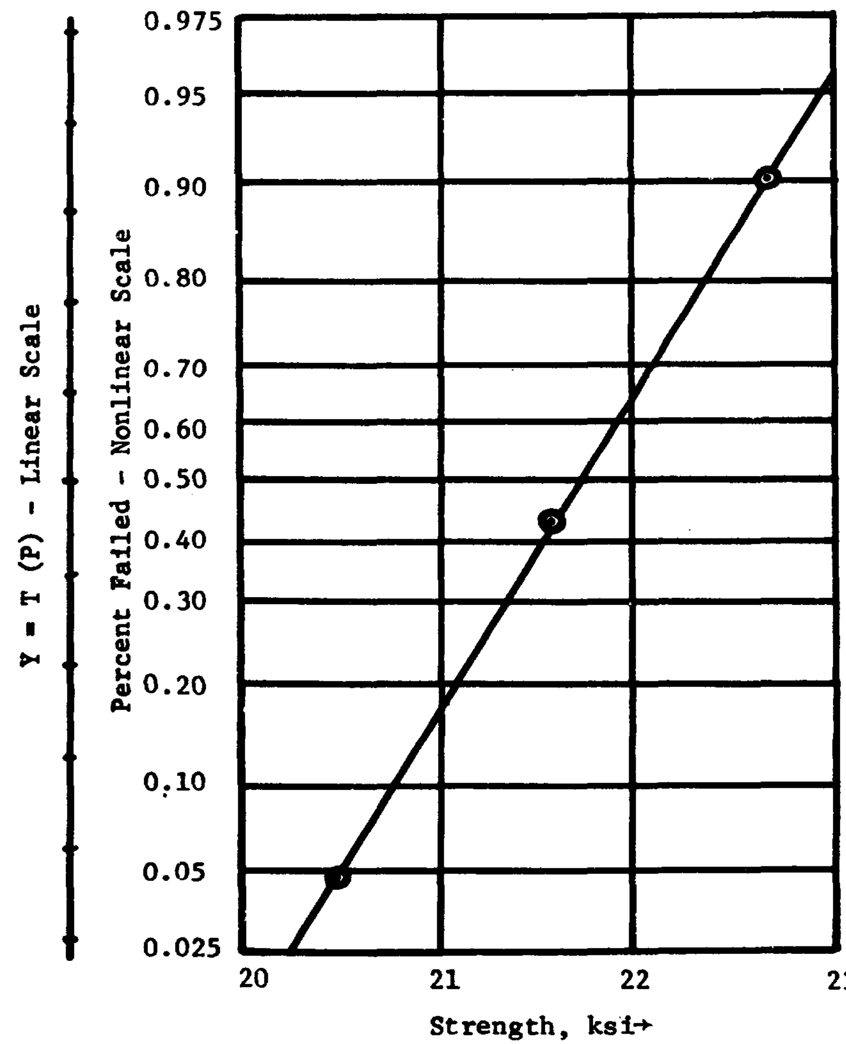


Figure 6.6 Straight Line Mode of Cumulative Distribution Function

Either or both the abscissa scale and the ordinate scale may be transformed for linearizing the frequency distribution functions. In the following section the linearizing transformation equations are derived.

6.4.1 Weibull Distribution

The general expression for the Weibull cumulative distribution function, Equation 6.13, is:

$$p = 1 - e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^b} \qquad X_o \leq x \leq \infty$$

with original variables

P = probability of failure

x = strength

or,

$$\frac{1}{1-p} = e^{\left(\frac{x-X_o}{\theta-X_o}\right)^b}$$

$$\ln\ln\left(\frac{1}{1-p}\right) = b \ln (x-X_o) - b \ln (\theta-X_o) \ . \qquad (6.23)$$

This has a form of $Y = \beta_X + \alpha$ where:

$$Y = \ln\ln \frac{1}{1-p} \qquad (6.24)$$

$$X = \ln (x-X_o) \qquad (6.25)$$

$$\beta = b \qquad (6.26)$$

$$\alpha = -b \ln (\theta-X_o) \qquad (6.27)$$

The Equations (6.24) and (6.25) respectively for ordinate and abscissa scales, are the linearizing transformation equations for Weibull distribution. Hence, if the new scales (ordinate and abscissa) are constructed corresponding to these equations, the points following Weibull distribution should plot as a straight line on these new scales.

6.4.2 Normal Distribution

In the case of Weibull distribution, the density function (Equation 6.12) can be integrated in the closed form to give the cumulative distribution function (Equation 6.13),

$$P(x) = 1 - e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^b} ,$$

whereas in the case of Normal distribution, it is not possible to integrate the density function in the closed form to give Normal cumulative distribution function. Hence, this is expressed as:

$$P(x) = \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$

Whereas, in the case of Weibull distribution, the Equation 6.13 can be transformed into a straight line function (See Equation 6.23), there is no simple transformation for the case of Normal distribution that can be used to relate the original variable $P(x)$ to a linear mode variable, which is $\ln\ln \frac{1}{1-P(x)}$ in the case of Weibull. Hence, the following method was used to linearize the Normal distribution.

The general equation of the linear form (straight line) of a distribution is:

$$Y = \alpha + \beta X \tag{6.28}$$

where X is some function of strength x [for example, $X = \ln (x-X_0)$, for Weibull] and Y is some function of probability P(for example, $Y = \ln\ln \frac{1}{1-P}$). Since Y is not a simple function of probability (P), one needs to find a new variable which should satisfy the Equation (6.28), and it should be related to P in such a manner that it can be used to find necessary values of this new variable for any given corresponding value of P.

Such a variable can be the standardized normal variate, z. The standardized normal variate, z;

1. is related to P values and could be found directly from the Tables of Normal distribution, such as given in Section 2, Table 2.1.

2. satisfies the Equation (6.28). This is shown below:

z is expressed as:

$$z = \frac{x-\mu}{\sigma}$$

or

$$z = \left(\frac{1}{\sigma}\right) X - \left(\frac{\mu}{\sigma}\right)$$

This has the same form as Equation (6.28), where

$$Y = z,\ \frac{1}{\sigma} = \beta,\ -\frac{\mu}{\sigma} = \alpha, \text{ and } x = \text{strength}.$$

Hence, the linearizing transformation equations for Normal distribution are:

$$Y = z, \text{ the Standardized Normal Variate} \tag{6.29}$$

$$X = x \tag{6.30}$$

If the transformation just described does linearize the Normal distribution function, it will plot as a straight line on a Cartesian paper. A graphical example demonstrating the linearization of Normal distribution is shown:

The Normal distribution function with a mean of $\mu = 28$ and $\sigma = 4.25$ was plotted on a Normal probability paper (See Figure 6.7) from which the following values of x and its corresponding values of P were selected:

x	P
15	.0015
20	.035
25	.25
35	.95

For the corresponding values of P, the values of z were found from the Tables of Normal distribution:(9)

x	P	$T\{P\} = z = \frac{x-\mu}{\sigma}$
15	.0015	2.97
20	.035	1.82
25	.025	0.67
35	.95	-1.65

The values of x on the abscissa and z on the ordinate were plotted on a Cartesian coordinate paper, and the resultant plot was found to be a straight line (See Figure 6.8). Hence, this proved that this method did linearize the Normal distribution and the linearizing transformation equations are Equations (6.29) and (6.30);

$$Y = z$$

$$\text{and} \quad X = x \ .$$

6.4.3 Extreme Value Distributions

The general expression for the cumulative distribution function of the Largest Extreme Value distribution is, from Equation 6.20):

$$P = e^{-e^{-\beta\ (x-M)}} \ .$$

By taking the ln twice, this equation reduces to a form of a straight line:

$$-\ln\ln\left(\frac{1}{P}\right) = \beta x - \beta M \qquad (6.31)$$

or $$Y = \beta x + \alpha$$

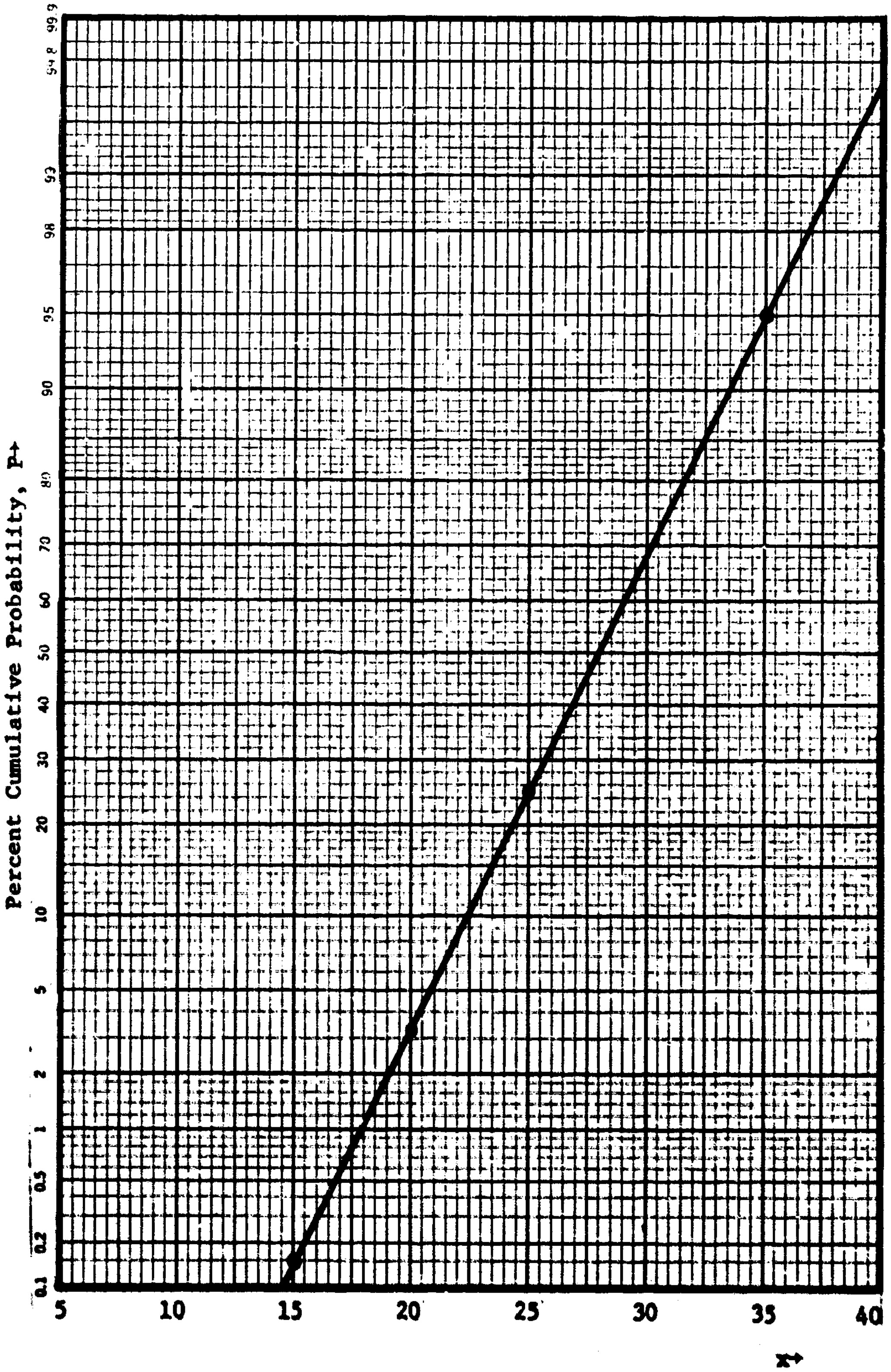


Figure 6.7 Plot of x vs. P on Normal Probability Paper

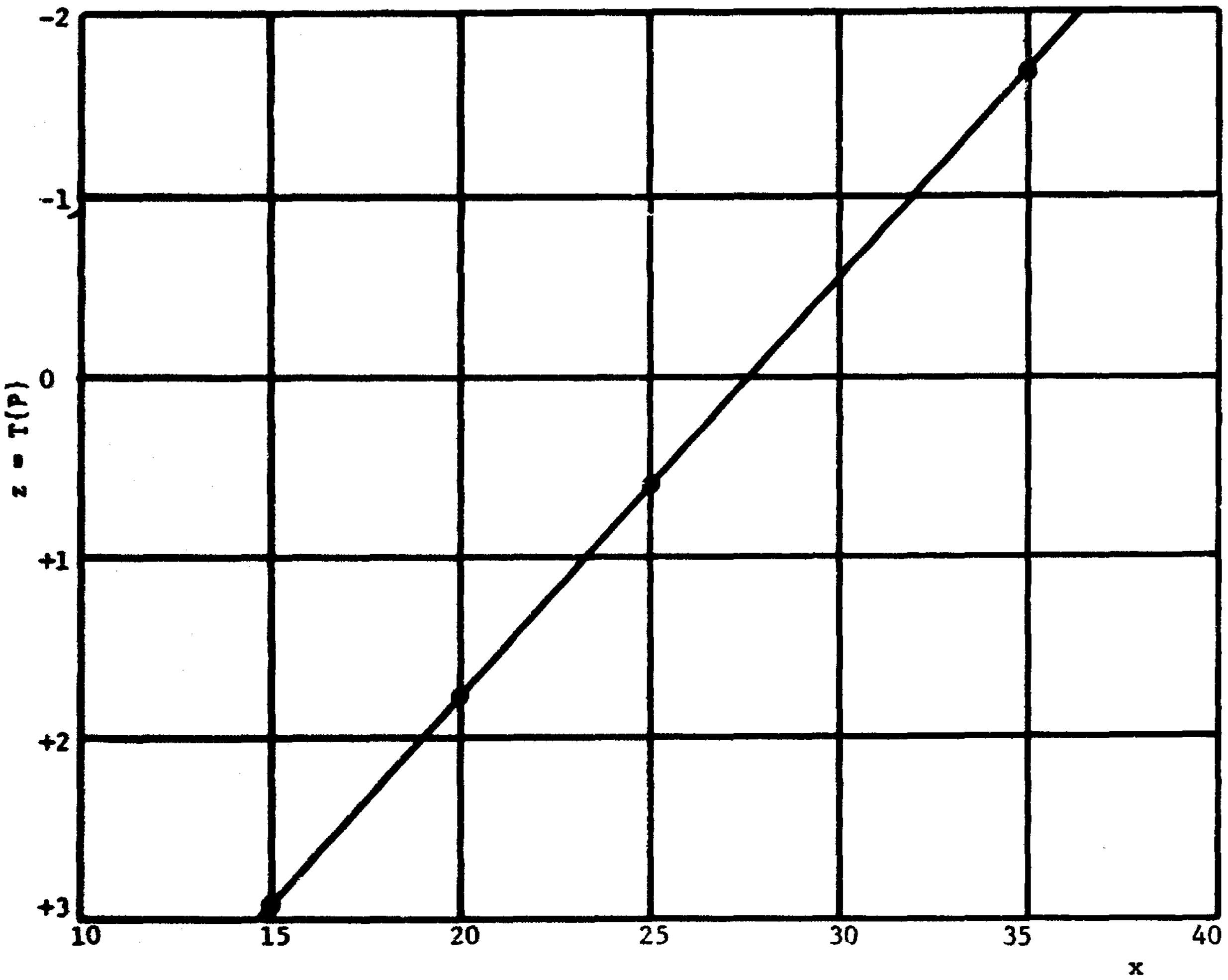


Figure 6.8 Plot of x vs. z on Cartesian Paper

where $$Y = -\ln\ln\left(\frac{1}{P}\right) \tag{6.32}$$

$$X = x \tag{6.33}$$

$$\alpha = -\beta M \tag{6.34}$$

Equations (6.32) and (6.33) are linearizing transformation equations for Largest Extreme Value distributions. For Smallest Extreme Value distributions, the linearizing transformation Equations (6.35) and (6.36) were found in a similar manner. They are:

$$Y = \ln\ln \frac{1}{1 - P} \tag{6.35}$$

$$X = x \tag{6.36}$$

$$\alpha = -\beta M \tag{6.37}$$

6.5 FITTING THE LINEARIZED DISTRIBUTION TO THE STRENGTH DATA

In the previous sections, the parameters, the linearizing transformation equations, and the linear mode variables of the distribution functions used in this study were presented. The best fitting distribution is the one which has the highest correlation coefficient, R. In order to determine the values of R for each distribution, they should be fitted to Probability-Strength (P,x) data by fitting a least squares line ($Y = \alpha + \beta X$) to the linear mode variables of these data. This was done for all the distributions in the following manner:

6.5.1 Weibull Distribution

The original variables of the data are Probability and Strength (P and x). From the linearizing transformation Equations (6.24) and (6.25);

$$Y = \ln\ln \frac{1}{1 - P}$$

and $X = \ln (x-X_o)$, the linear mode variables are $\ln\ln \frac{1}{1 - P}$ and $\ln (x-X_o)$, where x is the original variable (strength), P is the cumulative probability from the median rank table, X_o is the lower bound of strength, and X and Y are the linear mode variables.

By substitution of X and Y in Equations (6.2) and (6.3), the values of the parameters α and β for the least squares line ($Y = \alpha + \beta X$) were computed:

$$\beta = \frac{n\left[\sum_{i=1}^{n} \left(\ln\ln \frac{1}{1-P_i}\right) \ln(x_i-X_o)\right] - \sum_{i=1}^{n} \ln (x_i-X_o) \sum_{i=1}^{n} \left(\ln\ln \frac{1}{1-P_i}\right)}{n \sum_{i=1}^{n} [\ln(x_i-X_o)]^2 - \left[\sum_{i=1}^{n} \ln(x_i-X_o)\right]^2} \tag{6.38}$$

$$\text{and } \alpha = \frac{\sum_{i=1}^{n} \left(\ln\ln \frac{1}{1-P_i}\right) - \beta \sum_{i=1}^{n} \ln (x_i - X_o)}{n} \tag{6.39}$$

In order to compute α and β it was first necessary to determine X_o from the Probability-Strength (P, x) data. Once the X_o was determined, the values of α and β were computed, and the correlation coefficient R was found by substituting the values of α and β in Equation 6.6. In the past investigation(1), X_o was determined by a graphical method; in the present investigation this was done by a computer approach, as follows:

1. A value for X_o was assumed which should be somewhere between zero and the lowest strength value of the test data. Let this X_o be $X_o(1)$.

2. Once the value of X_o is known or assumed, the original variables of the data points can be transformed to the linear mode variables by using the transformation equations

$$Y = \ln\ln \frac{1}{1-P}$$

$$X = \ln (x-X_o).$$

3. By substitution of each value of X and Y corresponding to each value of the original data points (P,x) in Equations (6.2) and (6.3), the parameters α and β of the least squares line $Y = \alpha + \beta X$ were then computed.

4. Using the values of α and β, the value of correlation coefficient R for this fit was computed from Equation (6.6). Let this correlation coefficient be R(1).

5. Another X_o was then assumed close to (greater or less than) $X_o(1)$. Let this be $X_o(2)$. The steps 1 through 4 were repeated. Let the correlation coefficient thus computed be R(2).

6. The next value of $X_o=X_o(3)$ was then computed in the following manner: (See Figure (6.9)
Whenever the ratio $\frac{\Delta R}{\Delta X_o} = \frac{R(2)-R(1)}{X_o(2)-X_o(1)}$ is positive, the value of $X_o(3)$ was assumed to be larger than $X_o(2)$; and if the ratio is negative, the value of $X_o(3)$ was assumed to be smaller than $X_o(2)$. The larger the standard deviation of the strength data, the larger will be the difference $[X_o(3) - X_o(2)]$ that can be assumed.

7. After $X_o(3)$ was found, the steps 2,3, and 4 were repeated; the corresponding value of correlation coefficient R(3) was computed.

8. This was repeated twelve times, and twelve X_o's and their corresponding values of R were computed. (Note: The number of repetitions, twelve, was selected arbitrarily).

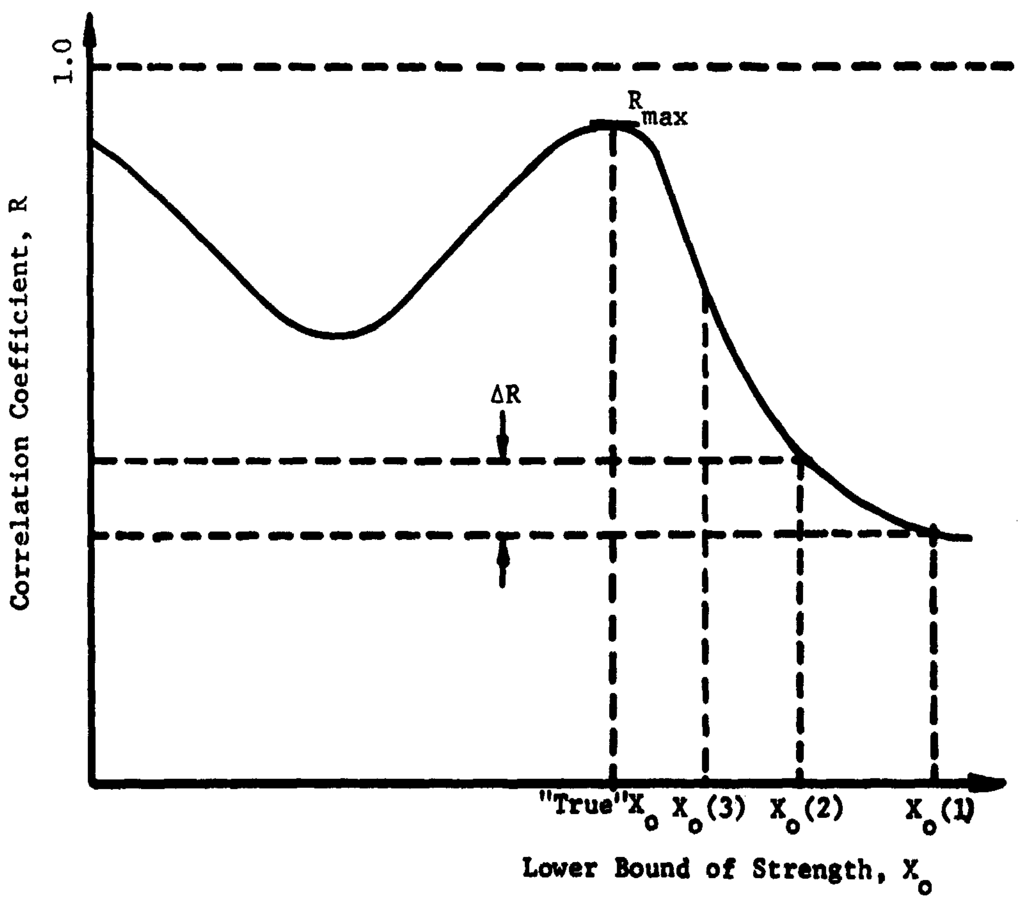


Figure 6.9 Determination of X_o by Trial and Error Method

Out of these 12 lower bound X_o's, the one which gave the maximum correlation coefficient (R) (the best fit) was taken as the "true" lower bound of strength X_o. Once the true value of X_o was determined, this and the values of x and P were substituted in Equations (6.38) and (6.39) to compute α and β; and, subsequently, the correlation coefficient R was determined from Equation (6.6).

6.5.2 Normal Distribution

To fit a Normal distribution to a set of data means fitting a straight line (least squares line $Y = \alpha + \beta X$) such that:

$Y = z$, the standardized Normal variate

and $X = x$, the fatigue strength.

The values of z correspond to the values of median ranks, and they were found from the Normal Distribution Table.[9]

For example, if the total number of test points is three, their coresponding values of median ranks are (2): .2063, .5000 and .7937 as read from the median ranks table. These values represent the areas under the Normal distribution curve (See Figure 6.10). Hence, the values of z corresponding to the values of the median ranks, .2063, .5000, and .7937 are −.8194, 0, and +.8194 as read from the Normal Distribution Table. The values of z or median rank z values were found in the similar manner for various values of median ranks. The table of median rank z values similar to the table of median ranks was constructed, see Table 6.1. These tables of median ranks and median rank z values, which are in matrix form, were stored into the computer for the purpose of the data analysis. The values of $X = x$ (fatigue strength) and $Y = z$ (the corresponding value of the standardized Normal variate) were substituted in Equations 6.2 and 6.3, and α and β were computed to give the equation of the least square line, $Y = \alpha + \beta X$, fitted through these points.

The next step was then to determine the correlation coefficient R. This was done using the Equation 6.6.

Since the Normal distribution is a little more involved than the other distributions (Weibull and Extreme Value), an example is given to illustrate the procedure of fitting the Normal distribution to data.

Suppose the fatigue strength distribution data at 10^5 life cycles are: 27.0, 24.0, 32.5, and 29.0 ksi. (Although the number of test points were at least 10 or more in our study, four test points are given to make the correlation simple.)

The data were then arranged in an increasing order of value and the appropriate median ranks z values for sample size n = 4 were read from Table 6.1 as follows.

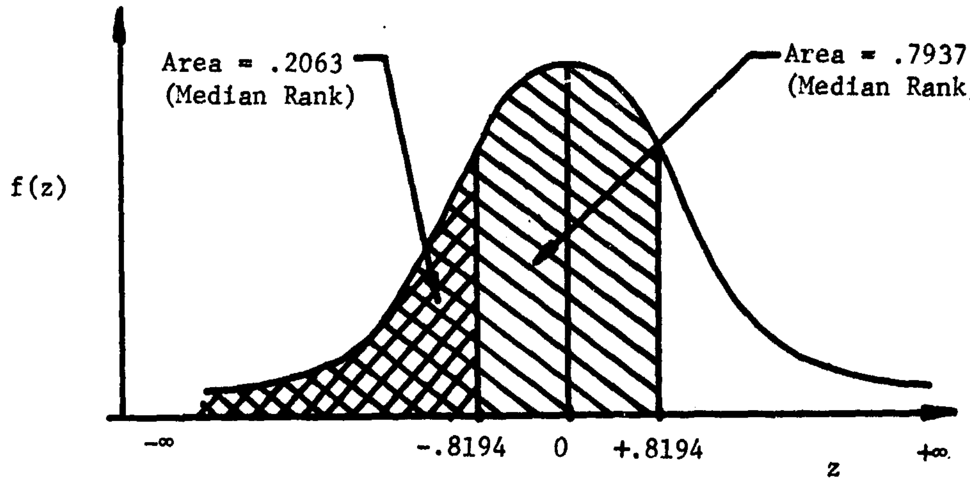


Figure 6.10 Illustration for the Median Rank z Values

MEDIAN RANKS z VALUES

Order Number, j	Sample Size, n: 1	2	3	4	5 40
1	0.0000	-0.5450	-0.8194	-0.9982	-1.1290
2		+0.5450	0.0000	-0.2887	-0.4826
3			+0.8194	+0.2887	0.0000
4				+0.9982	+0.4826
5					+1.1290
.					
.					
.					
.					
40					

Table 6.2 Median Ranks z Values

x, ksi	Median Ranks z Values
24.0	-0.9982
27.0	-0.2887
29.0	+0.2887
32.5	+0.9982

By substitution of X = x and Y = z values in Equations (6.2) and (6.3), they reduced to:

$$\beta = \frac{n \sum_{i=1}^{n} z_i x_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} z_i}{n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}$$

and $$\alpha = \frac{\sum_{i=1}^{n} z_i - \beta \sum_{i=1}^{n} x_i}{n}$$

The values of α and β were then computed to determine the equation of the least squares line, Y = α + βX. Knowing the value of β, the correlation coefficient R was determined from Equation 6.6:

$$R = (\beta)^2 \frac{S_x^2}{S_y^2} = (\beta)^2 \frac{S_x^2}{S_z^2}$$

where $$S_x^2 = \frac{n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}{n(n-1)}$$ Sample Variance of x (abscissa)

and $$S_y^2 = \frac{n \sum_{i=1}^{n} z_i^2 - \left(\sum_{i=1}^{n} z_i\right)^2}{n(n-1)}$$ Sample Variance of z (ordinate)

6.5.3 Extreme Value Distributions

The linearizing transformation equations for Largest Extreme Value distribution (Equations 6.35 and 6.36) are:

$$Y = -\ln\ln\left(\frac{1}{p}\right)$$

and $$X = x \quad .$$

By substitution of X and Y in Equations (6.2) and (6.3), the values of the parameters α and β for the least square line (Y = α + βX) were computed:

$$\beta = \frac{n\left[\sum_{i=1}^{n} (-\ln\ln \frac{1}{P_i})\ (x_i)\right] - \sum_{i=1}^{n} (x_i) \sum_{i=1}^{n} (-\ln\ln \frac{1}{P_i})}{n \sum_{i=1}^{n} (x_i)^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \tag{6.40}$$

and
$$\alpha = \frac{\sum_{i=1}^{n} (-\ln\ln \frac{1}{P_i}) - \beta \sum_{i=1}^{n} (x_i)}{n} \tag{6.41}$$

Knowing the value of β, the correlation coefficient R was determined from Equation (6.6).

$$R = (\beta)^2 \frac{S_x^2}{S_y^2}$$

where
$$S_x^2 = \frac{n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}{n(n-1)} \quad \text{Sample Variance of x (abscissa)} \tag{6.42}$$

and
$$S_y^2 = \frac{n \sum_{i=1}^{n} (-\ln\ln \frac{1}{P_i})^2 - \left[\sum_{i=1}^{n} (-\ln\ln \frac{1}{P_i})\right]^2}{n(n-1)} \quad \text{Sample Variance of y (ordinate)} \tag{6.43}$$

where $y = -\ln\ln \frac{1}{P}$

In a similar manner, Smallest Extreme Value distribution was fitted to the data such that:

$$Y = \ln\ln \frac{1}{1-F}$$

and $X = x$.

The values of α and β were computed using Equations (6.2) and (6.3) and the correlation coefficient R using Equation (6.6).

6.6 DETERMINATION OF THE BEST FITTING DISTRIBUTION AND ITS PARAMETERS

In the previous sections, the statistical distributions, their parameters, and their linearizing transformation equations were discussed. The distributions were then fitted to the data by fitting a least squares line ($Y = \alpha + \beta X$) to the linear mode variables of these data by computing the values of α and β from Equations (6.2) and (6.3). Knowing α and β, the

the correlation coefficients R were determined from Equation (6.6). The best fit distribution was the one which had the largest value of correlation coefficient R. This distribution could be taken as the "true" representation of the scatter of the strength data. The linear mode of the distributions [for example, $\ln(x-X_o)$ and $(\ln\ln \frac{1}{1-p})$ for Weibull] are not used in practice, and therefore, the original parameters (b, X_o, and θ for Weibull) of the distribution should be computed. These parameters were determined from the slope β and the interception α of the fitted least squares line. This could be done by using the inverse-transformation equation as mentioned in Section 6.4. The specific inverse-transformation equations to compute the parameters of the four distributions used in this study are given in the following sections.

6.6.1 Weibull Distribution

As mentioned before, Weibull distribution has three parameters. They are:

X_o = lower bound of strength

b = the slope

θ = characteristic strength

The method of determining the value of X_o was explained in Section 6.5.1. b is also the slope of the least squares line whose parameters are α and β. Therefore, $b = \beta$. θ was determined from Equation 6.27:

$$\alpha = -b\ln(\theta - X_o)$$

$$\ln(\theta - X_o) = -\frac{\alpha}{b}$$

Therefore, $$\theta = e^{-\frac{\alpha}{b}} + X_o \tag{6.44}$$

and $$b = \beta \tag{6.45}$$

6.6.2 Normal Distribution

The Normal distribution has only two parameters. They are:

μ = mean

σ = standard deviation

The linear form of the distribution is expressed as

$$z = \frac{1}{\sigma}X - \frac{\mu}{\sigma} \quad ,$$

and the equation of the least squares line is :

$$Y = \beta X + \alpha \quad .$$

Hence, the parameters of this line are:

$$\alpha = -\frac{\mu}{\sigma}\ ; \quad \beta = \frac{1}{\sigma} \quad .$$

σ and μ were computed from rearranging these equations:

$$\sigma = \frac{1}{\beta} \tag{6.46}$$

$$\mu = -\sigma\alpha = -\frac{\alpha}{\beta} \tag{6.47}$$

6.6.3 Extreme Value Distributions

Both of these distributions have two parameters, and they are referred to as extremal parameters. However, in this study, these parameters are referred to as:

$$b = \text{slope}$$

$$M = \text{Mode}$$

The slope b is the slope of the least squares line (as it was the case for Weibull distribution). Hence, $b = \beta$.

The mode M was determined from Equation 6.34:

$$M = -\frac{\alpha}{\beta} \tag{6.48}$$

$$\text{and } b = \beta \tag{6.49}$$

These equations would apply to determine the parameters (M,β) for both Largest and Smallest Extreme Value distributions even though the numerical values of α and β would be different in each case.

Using the statistical and analytical tools discussed here, a computer program was developed whereby the computer prints out the fatigue strength distribution functions, their parameters, and the corresponding degree of fit (correlation coefficient R) for several preassigned lives.

Data on various non-ferrous materials under various conditions were collected and analyzed by computer-aided procedure as described above. The results are tabulated in Appendix 1 in terms of the best fitting distribution function and its parameters for several lives. The most representative parameters were then plotted, as shown in Figures 6.14 to 6.64. The discussion as related to these plots is given in Section 6.7.

6.7 GRAPHS OF THE FATIGUE STRENGTH DISTRIBUTION PARAMETERS

6.7.1 Expression of Data in Terms of Normal Parameters

By aid of the computer approach discussed in Section 6, the fatigue strength data were analyzed where different distributions (Weibull, Normal, Largest Extreme Value, and Smallest Extreme Value) were fitted to a set of data. The computer printed out the parameters and the degree of fit (correlation coefficient R) for each of these distributions for a given set of data.

This was done for various materials under various conditions. A representative computer output sheet for a material and conditions shown below is given in Table 6.2.

Material:	7075 Aluminum (Bar), S_u=86 ksi
Life:	10^5 cycles
Type of Loading:	Rotary Beam Bending
Theoretical Stress Concentration Factor:	K_t = 2.0
Other Conditions:	See Page 233 and Code Number (240)

The distribution with maximum value of correlation coefficient R was considered to be the best fitting distribution. For example, for the data given in Table 6.2, the maximum value of R is 0.948724, and this corresponds to Largest Extreme Value distribution. Hence, Largest Extreme Value distribution is the best fitting distribution of the fatigue strength of the above material under the given conditions. Its parameters are:

$$\text{BETA } (\beta) = .301634$$

$$\text{and} \quad \text{MODE } (M) = 35.155$$

The fatigue strength data of various non-ferrous materials under various conditions (effects) were analyzed in a similar manner. The results were tabulated in terms of only the best fitting distribution (this could be Largest Extreme Value, Smallest Extreme Value, Weibull, or Normal) and its parameters according to the materials in Appendix 1. The tabulated values were rounded to four digits. It was felt that the representative parameters should be plotted to study the effects of such factors as stress concentration, surface finish, type of loading, etc. on the distribution of the fatigue strength. This may lead to confusion as illustrated by the following example. Say, for a given material and conditions, the Weibull parameters are X_o, θ, and b with K_t = 2.4. However, for the same material and conditions, if the design should be changed so that K_t becomes 1.5, the distribution function may change from Weibull to Smallest Extreme Value (with parameters β and M); and if K_t should become 1.0, it may change to Normal (with parameters μ and σ).

When this information is plotted to determine the effect of stress concentration on the distribution parameters, a plot such as in Figure 6.11 results. This obviously cannot make much sense to the reader, as it is very difficult to compare one distribution's parameters (say X_o, b, and θ) for one value of effect (say K_t = 2.4) with another distribution's parameters (say β and M) for another value of the effect (say K_t = 1.5). This problem can be resolved by plotting all the data in terms of the <u>same</u> distribution. This means if, for example, Normal distribution is chosen, then the parameters of the other distributions should be expressed in terms of Normal parameters. This can be done by using, for <u>all</u> the test data, the values of the Normal parameters directly from the computer sheet (a sample is shown in Table 6.2). Al-

****

WEIBULL		SMALLEST EXTREME VALUE	
THETA (θ)	= 37.8210	BETA (β)	= .301694
X_d	= 30.5332	MODE (M)	= 38.701
b	= 1.9047		
R	= 0.889976	R	= 0.863512

****

LARGEST EXTREME VALUE		NORMAL	
BETA (β)	= .301634	MEAN (μ)	= 36.9284
MODE (M)	= 35.155	STD. DEVIATION (σ)	= 4.2207
R	= 0.948724	R	= 0.882308

****

Table 6.2 A Computer Output Data Illustrating the Distribution Parameters and the Corresponding Correlation Coefficients for a Given Set of Data

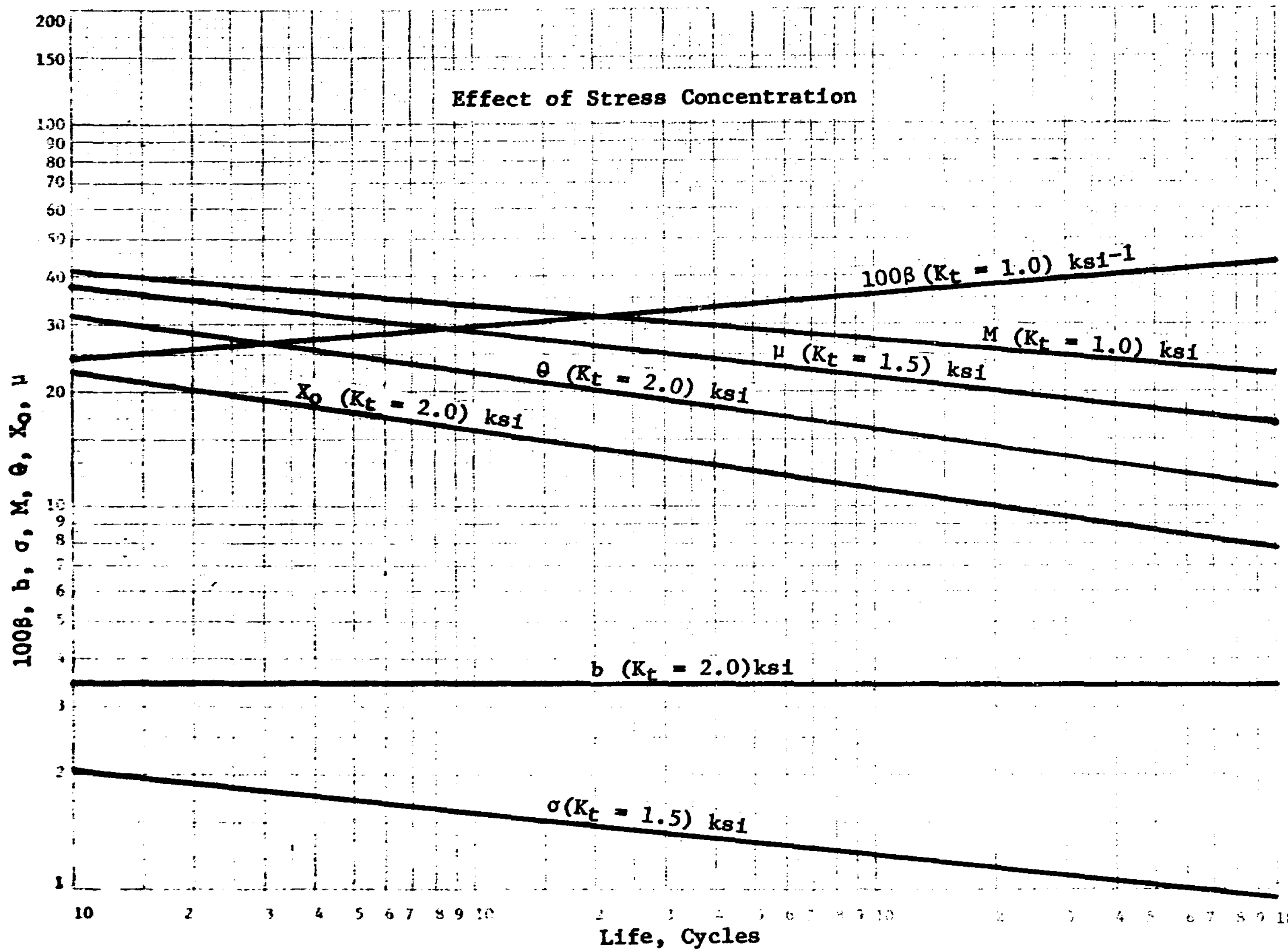


Figure 6.11 Plot of the Actual Distribution Parameters for Various Stress Concentration Factors

though in some cases the best fitting distribution might be other than the Normal distribution, it would not loose the significance by more than 5 to 10%. For example, from Table 6.2, if Normal distribution with $R = 0.882308$ (that is, 88.2%) is used instead of Largest Extreme Value (the best fitting distribution for this particular case) with $R = 94.9\%$, the level of significance of the fit is decreased by only 6.7% (94.9 - 88.2 = 6.7%). Although this approach results in somewhat lower accuracy, it has the advantage of greater clarity.

Out of the four distributions considered in the present investigation, Normal distribution, with parameters μ and σ, was selected for making these plots. The reasons for the selection of the Normal distribution are:

1. Normal distribution with its parameters μ (mean or average value) and σ (standard deviation or measure of scatter) is easier to understand for engineers with little statistical background.

2. The plot of these two parameters can be represented by a single line for each effect (See Figure 6.12) as compared to, say, Weibull, where three lines (one for each of the three parameters X_o, b, and θ) are needed to represent each effect.

3. Largest or Smallest Extreme Value distribution parameters (β and M) are not as easy to understand as in the case of Normal parameters.

It should be noted that: 1) the plots are meant only to represent the effect of different factors on the fatigue strength. For the purpose of solving the actual design problem, it is recommended that the actual distribution and its parameters be used from the tables in Appendix 1; 2) only the representative values from the entire analysis are plotted, whereas the tables in Appendix 1 give all the values.

6.7.2 Explanation of the Graphs

Mean strength μ was plotted against life on a log-log paper, one line representing only one effect (see Figure 6.12). To the right of the graph a specific value of σ/μ accompanies each line, this value being independent of life. Therefore, once μ is determined from a graph for a given life and given effect, σ can be calculated from the σ/μ value.

The meaning of σ/μ is discussed below:

For any given set of conditions at any given life the values of μ and σ were generated by the computer. Consider the illustrative example in Section 6.7.1 graphically shown by the line corresponding to $K_t = 2.0$ in Figure 6.12.

This is repeated in Figure 6.13. At 10^5 cycles, mean strength is μ_1. Locate at 10^5 cycles $(\mu_1 + \sigma_1)$, and through this point draw a line parallel to the original line. (The assumption for drawing parallel lines is justified in Section 6.2, specifically in Figure 6.4.) At 10^5 cycles in the example quoted above, $\sigma = 4.2207$ and $\mu = 36.9284$, and, therefore, $\sigma/\mu = \frac{4.2207}{36.9284} = .1145$. This in Figure 6.12 corresponds to σ_1/μ_1 at 10^5 cycles. At any other life such as 10^6, locate μ_2 and $(\sigma_2 + \mu_2)$. The following demonstrates that

7075 ALUMINUM (BAR)

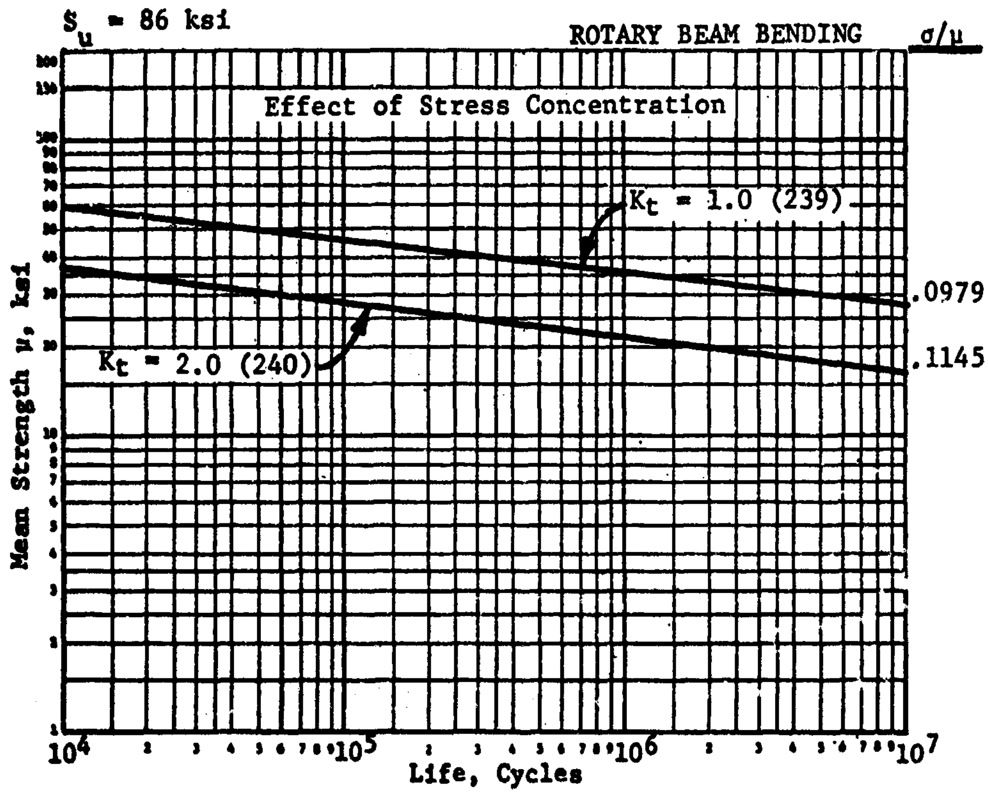


Figure 6.12 Plot of the Normal Parameters

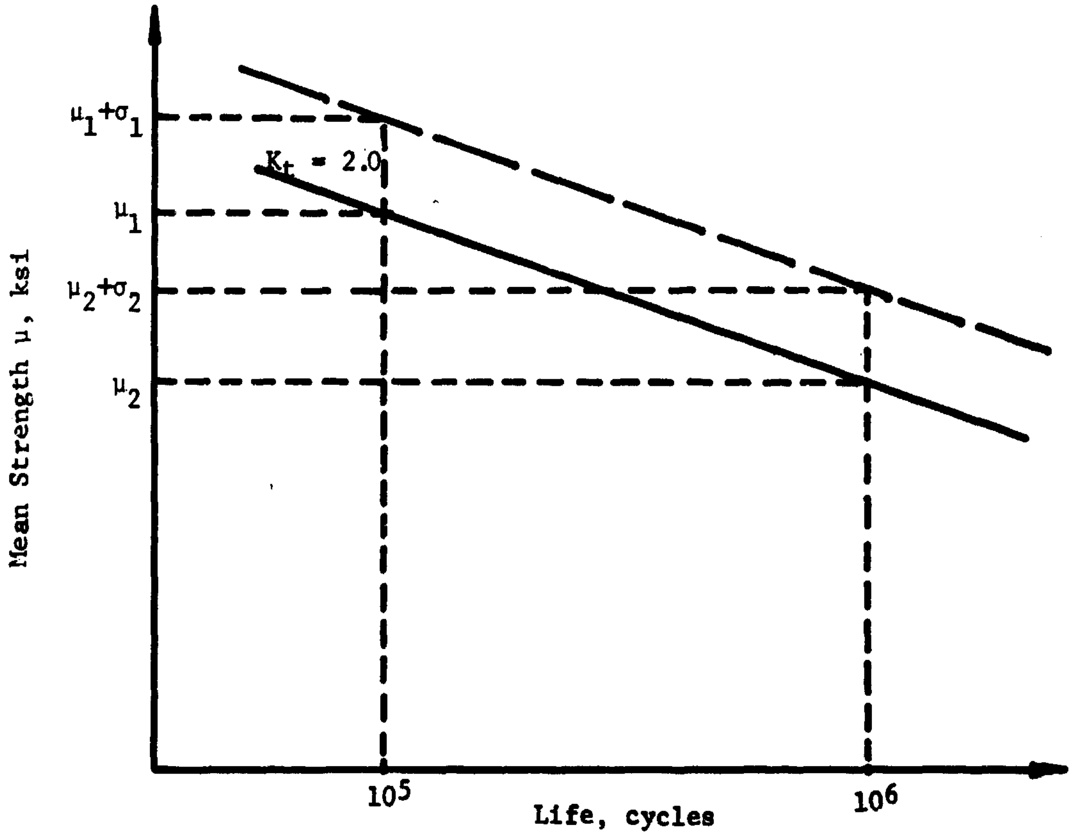

$\mu_1+\sigma_1$
$K_t = 2.0$
μ_1
$\mu_2+\sigma_2$
μ_2
Mean Strength μ, ksi
10^5
10^6
Life, cycles

Figure 6.13

$\sigma_2/\mu_2 = \sigma_1/\mu_1 = .1145$ and is thus independent of life. Since the lines are parallel (Figure 6.13),

$$\ln \mu_1 - \ln (\mu_1-\sigma_1) = \ln \mu_2 - \ln (\mu_2-\sigma_2)$$

or $$\ln \frac{\mu_1}{\mu_1-\sigma_1} = \ln \frac{\mu_2}{\mu_2-\sigma_2}$$

or $$\frac{\mu_1}{\mu_1-\sigma_1} = \frac{\mu_2}{\mu_2-\sigma_2}$$

or by simple algebra,

$$\frac{\sigma_1}{\mu_1} = \frac{\sigma_2}{\mu_2} = \text{Constant}$$

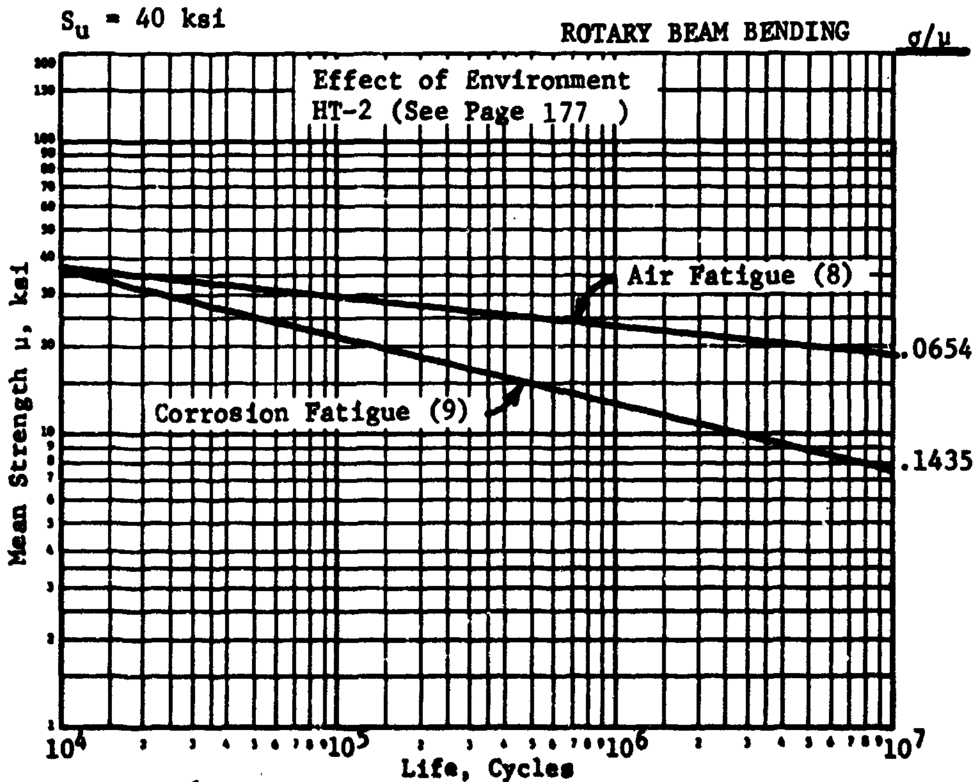
6.7.3 Use of Graphs

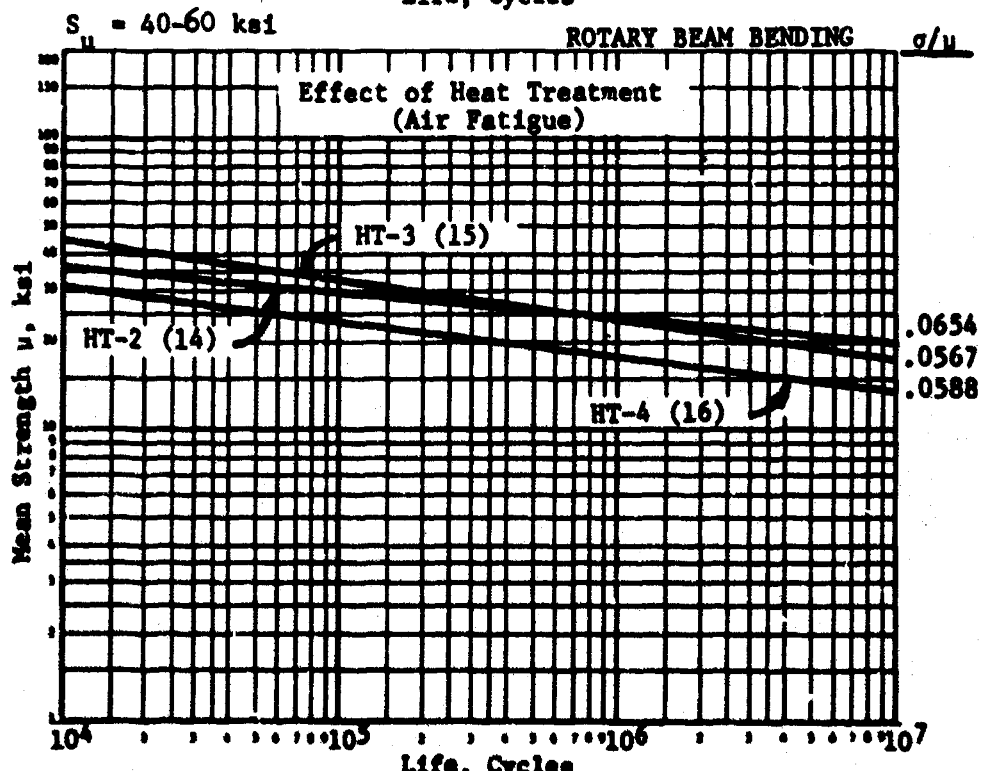
In this manner representative data were plotted for various materials and under various conditions. These are shown in Figure 6.14 to Figure 6.64 The use of these graphs can be illustrated by a representative example shown in Figure 6.12. For a life, say, 10^5 cycles and $K_t = 2.0$, the mean strength $\mu = 28.0$ ksi and $\sigma/\mu = 0.1145$. Therefore, $\sigma = 0.1145 \times 28 = 3.2$ ksi.

6.7.4 Graphs

INDEX TO GRAPHS OF NORMAL PARAMETERS
(Effect of Various Factors on Mean and Standard Deviation of Strength)

7.5 Zn - 2.5 Mg ALUMINUM

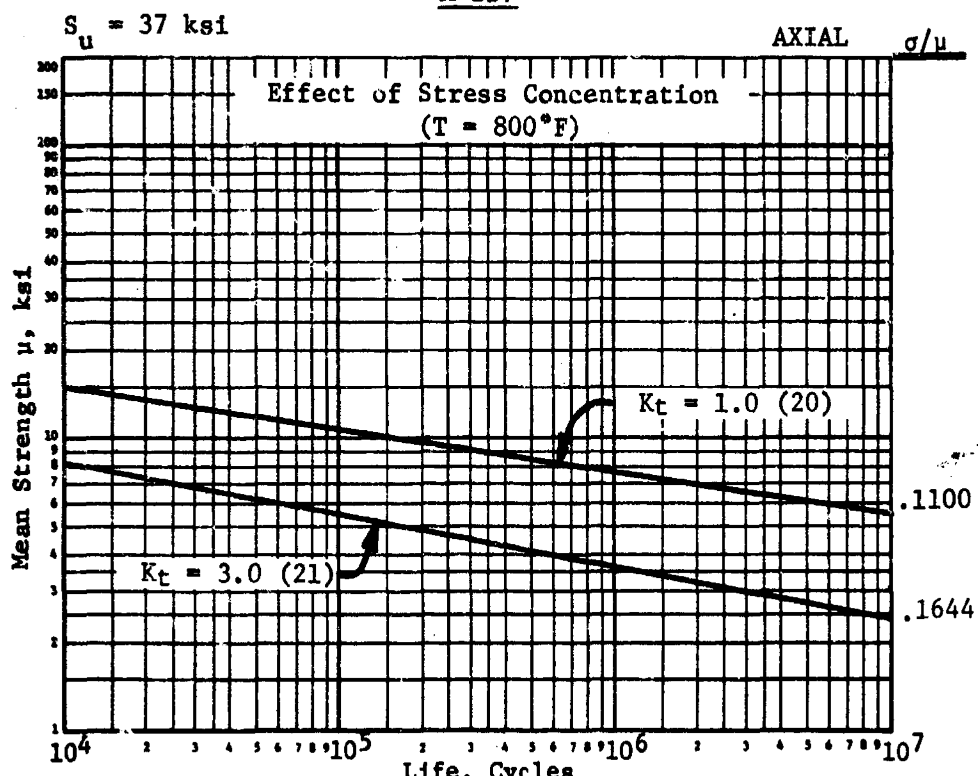


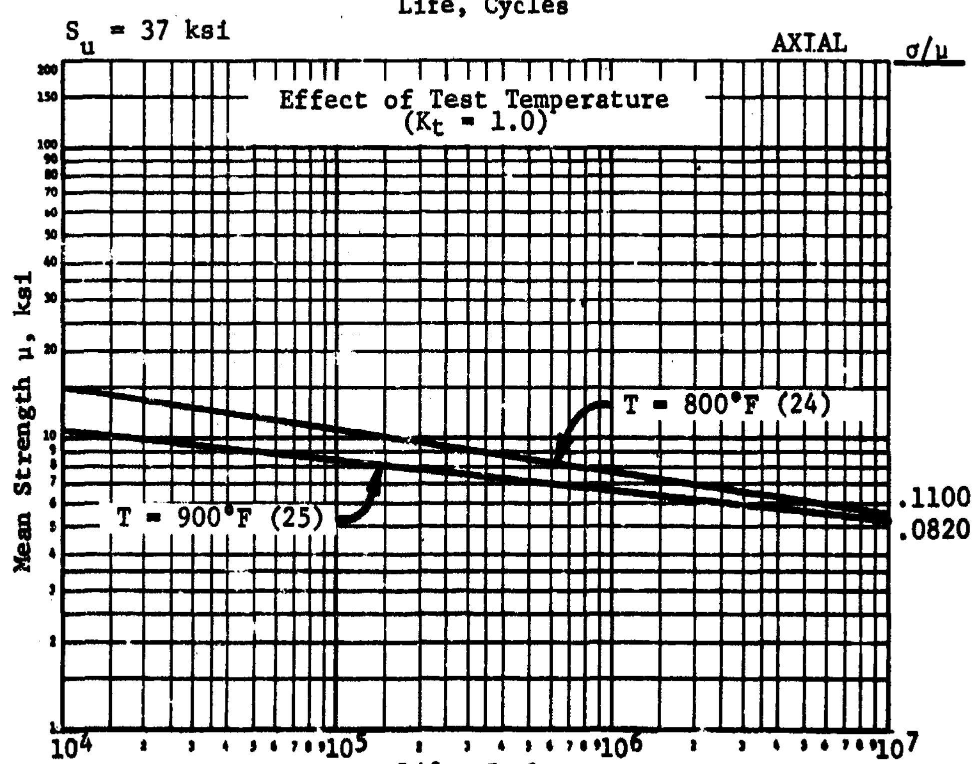


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.14

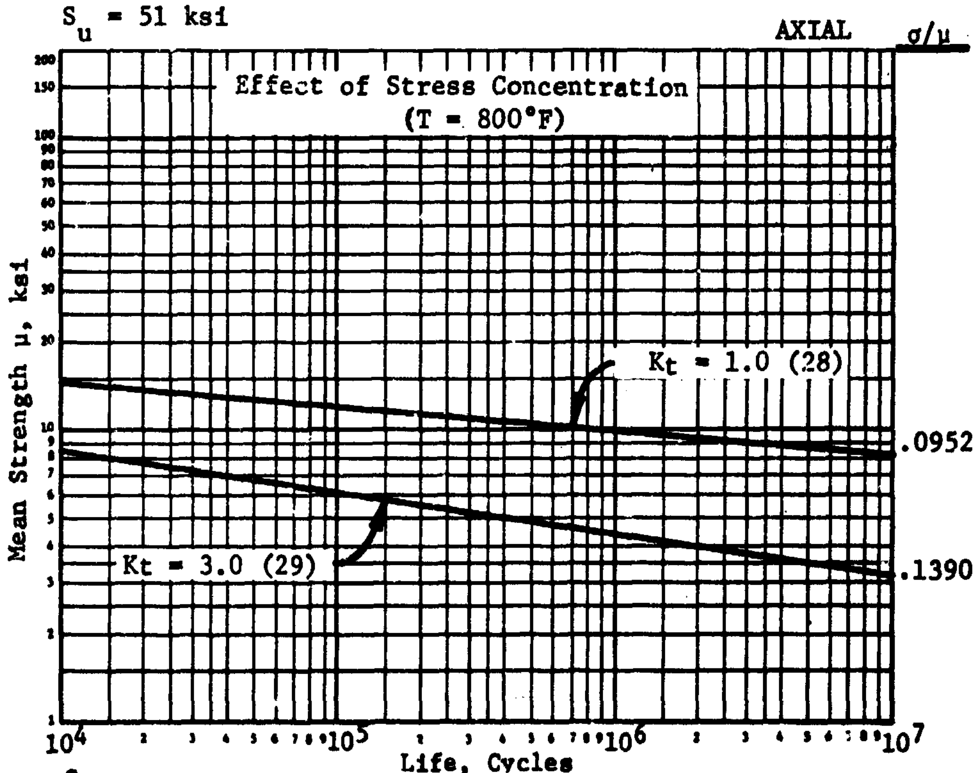
M-257

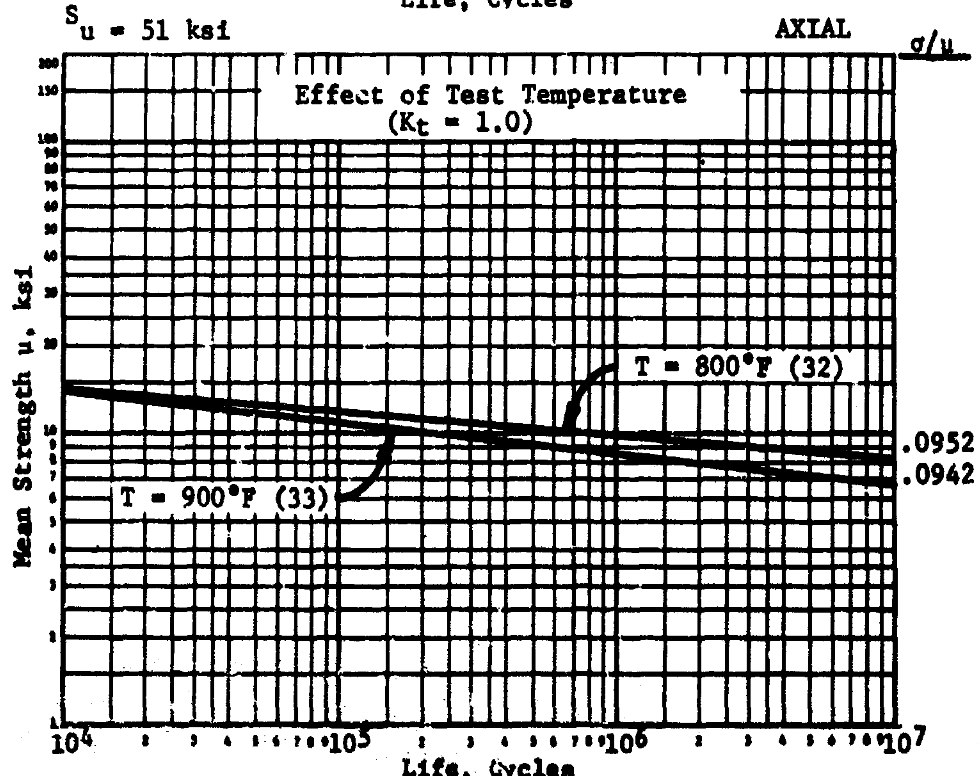




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.15

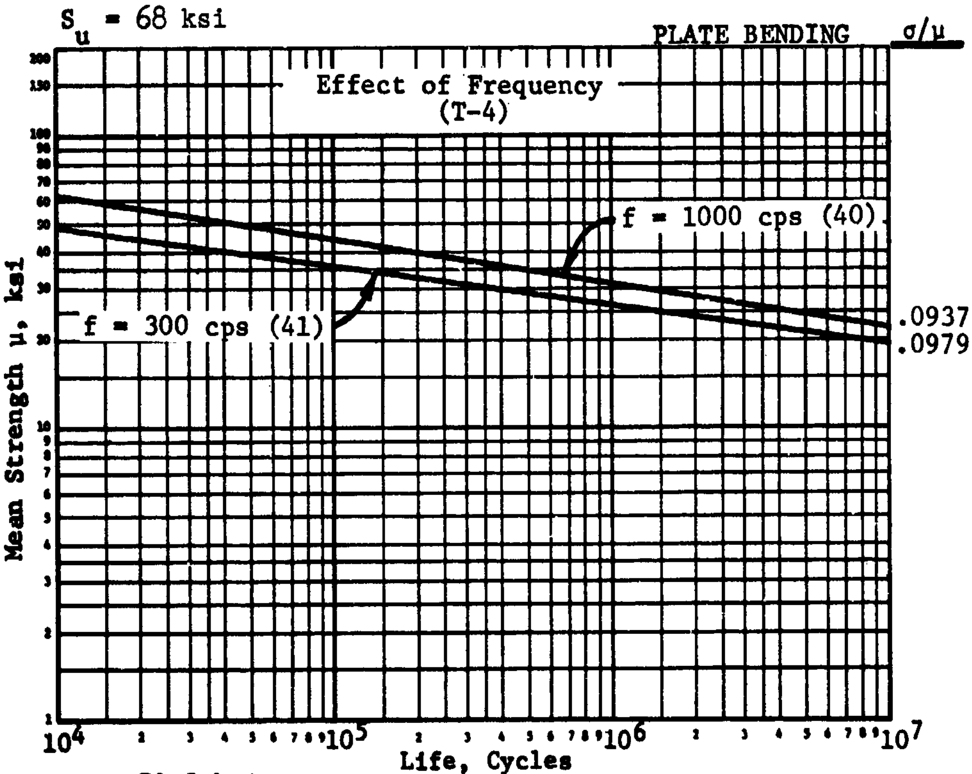


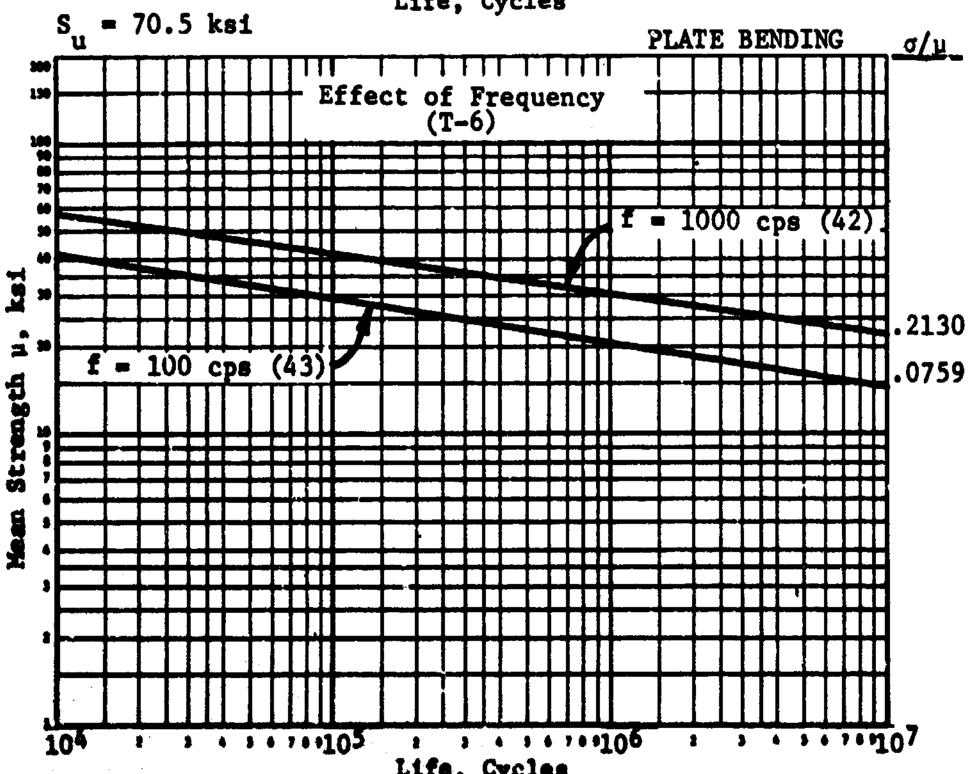


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.16

2014 ALUMINUM

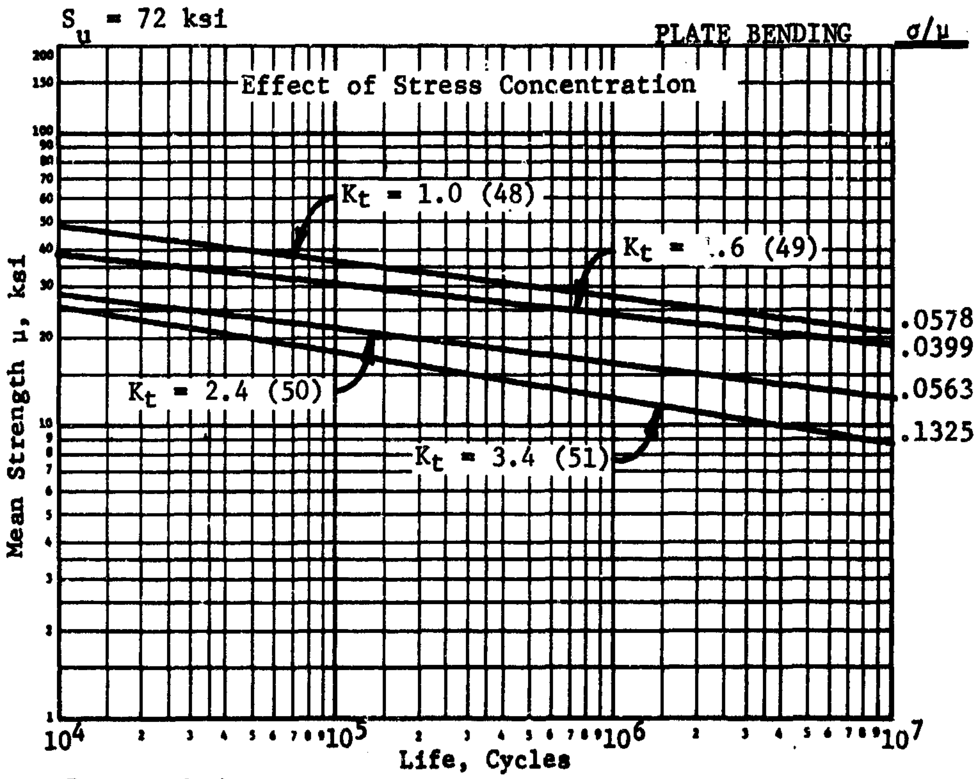


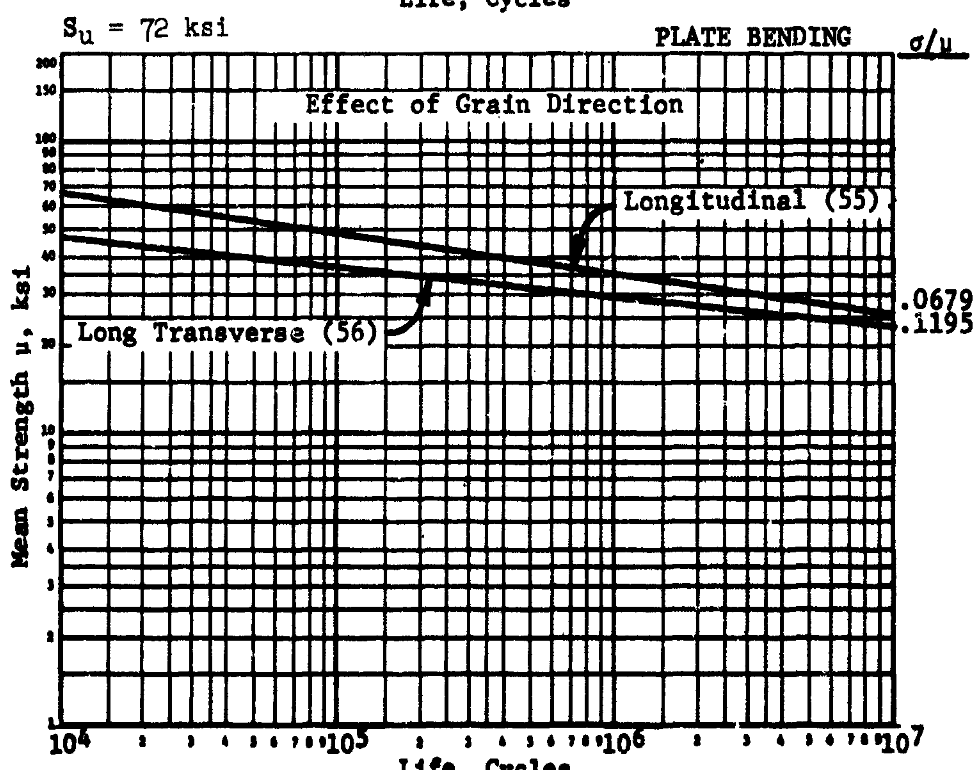


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.17

2014 ALUMINUM

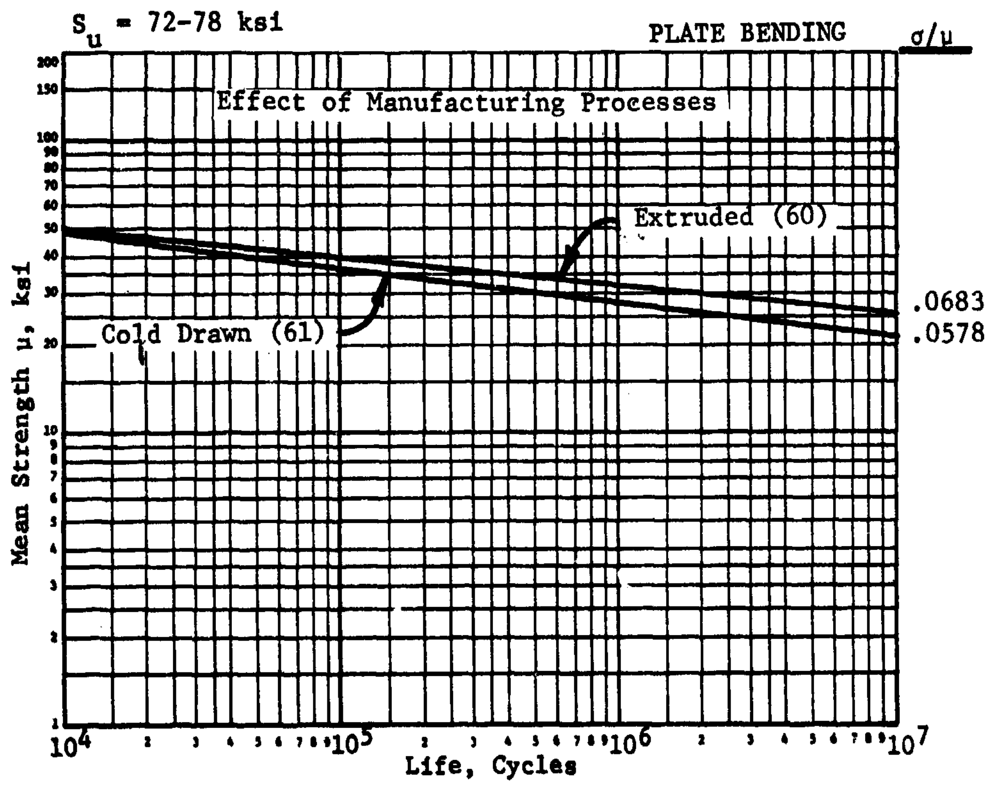


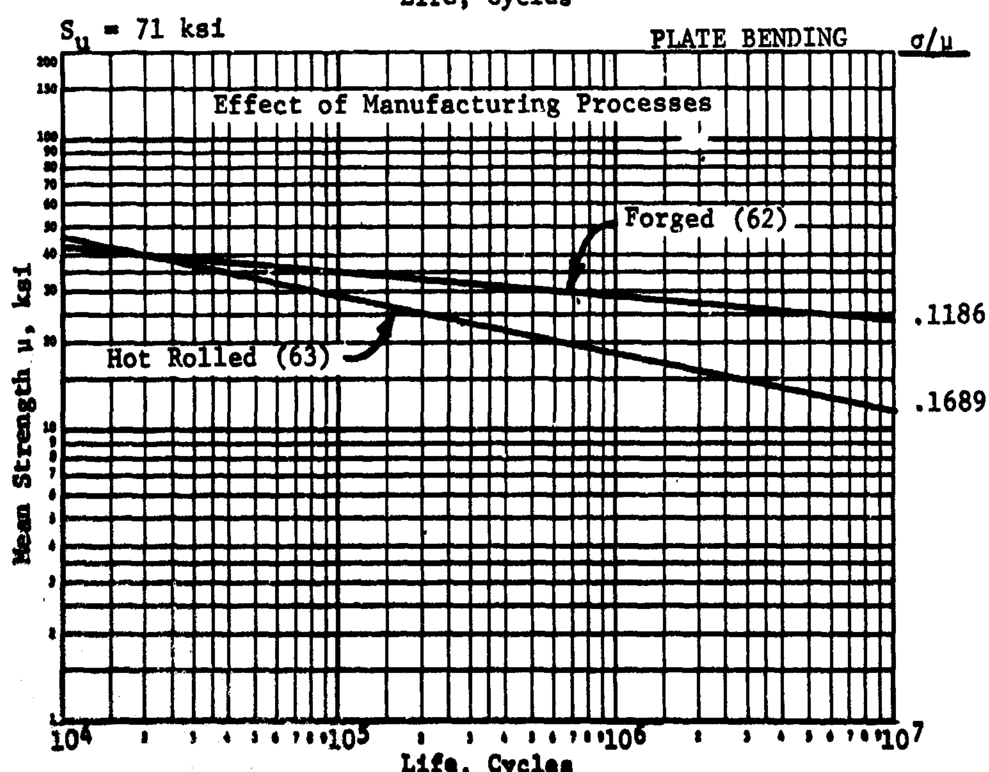


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.18

2014 ALUMINUM

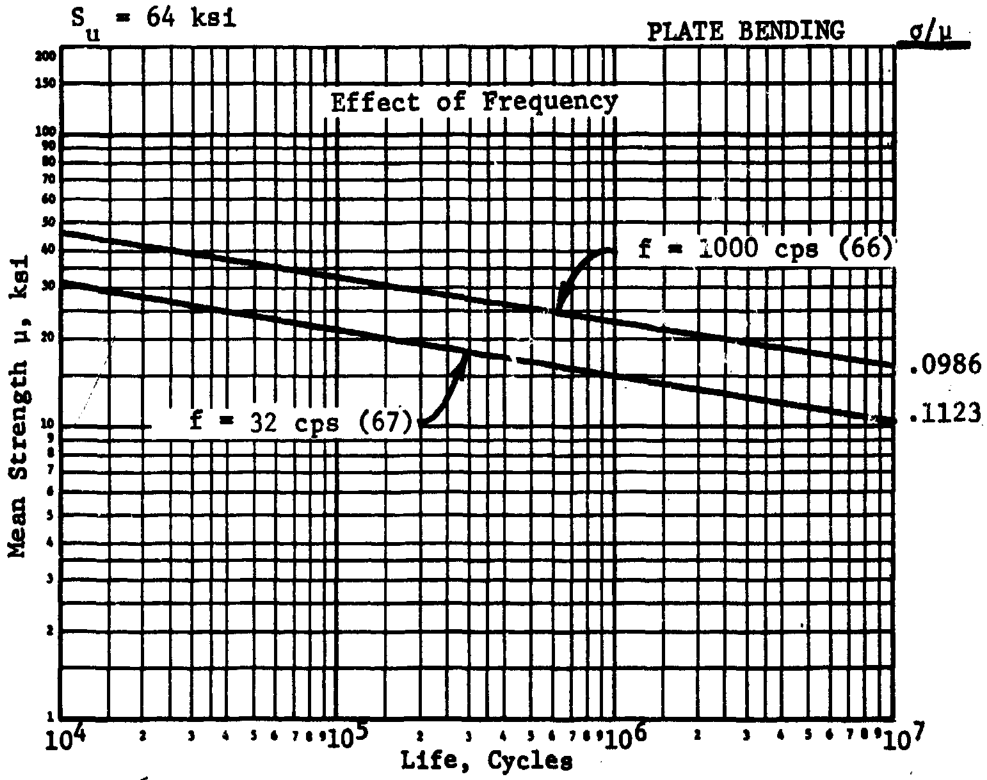


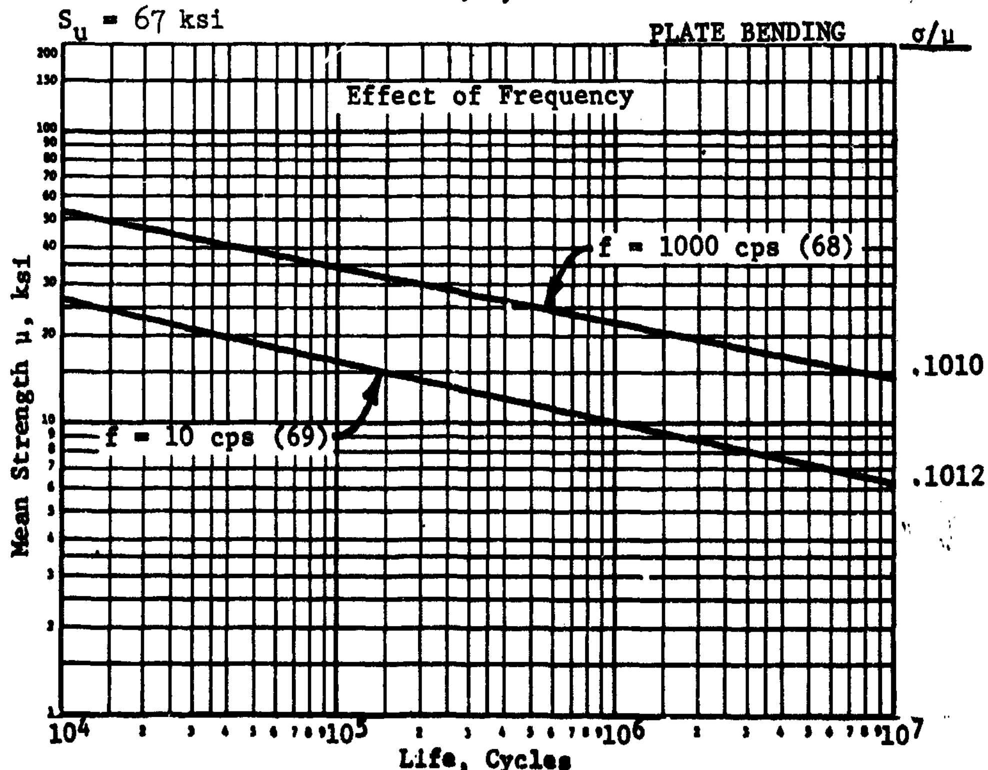


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.19

2014 ALCLAD ALUMINUM

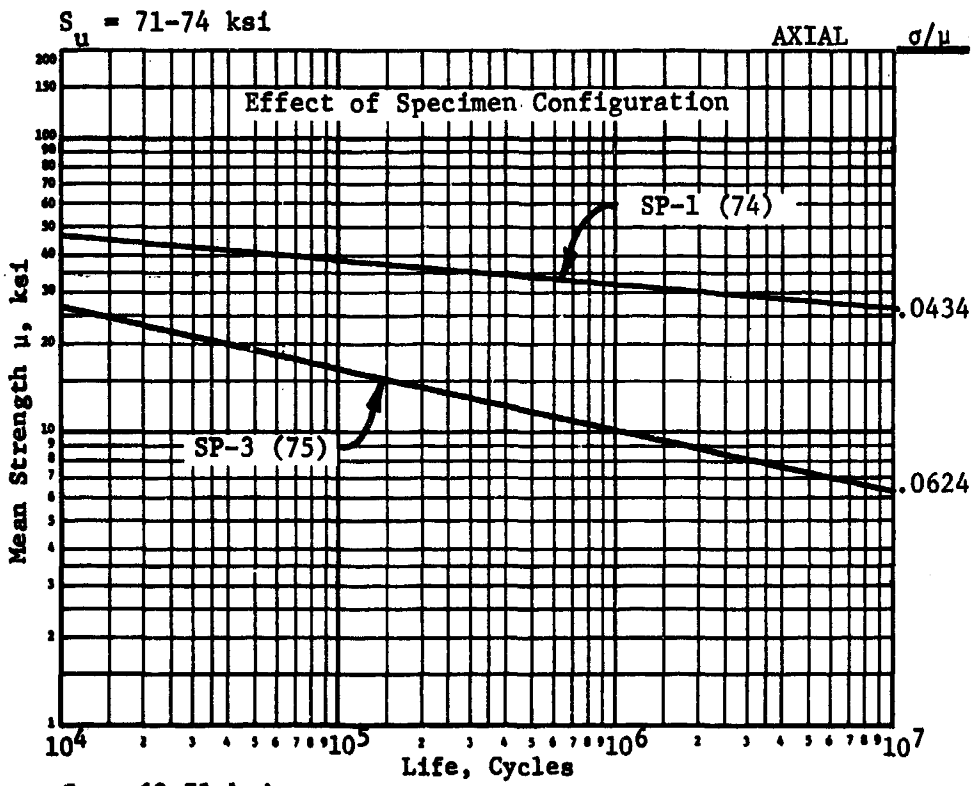


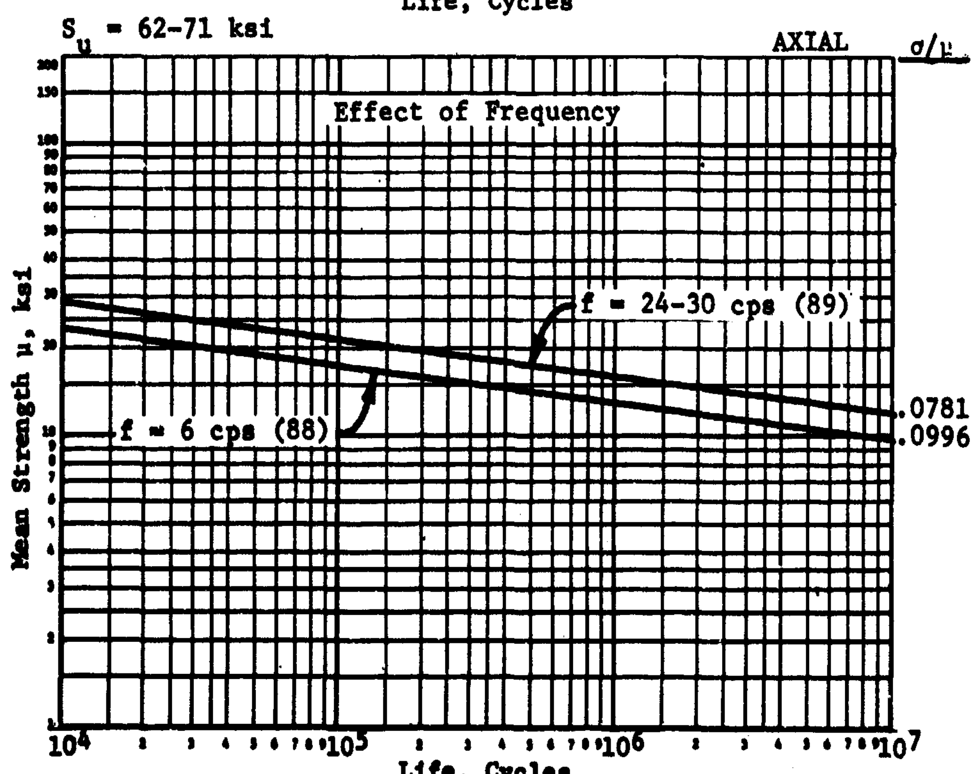


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.20

2024 ALUMINUM (SHEETS)

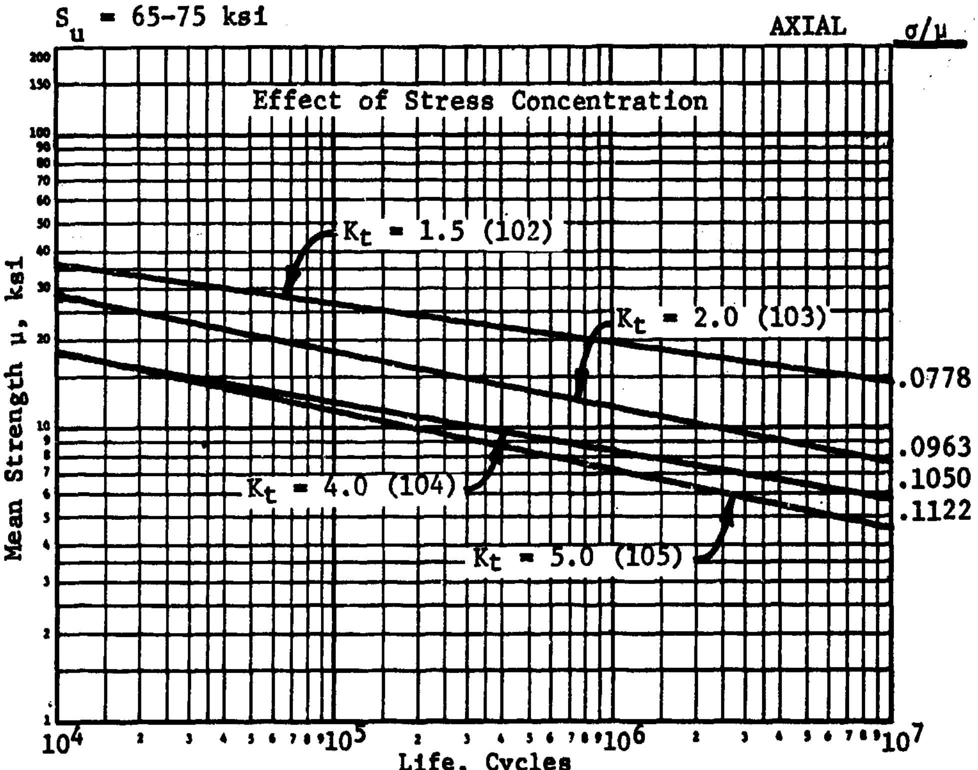


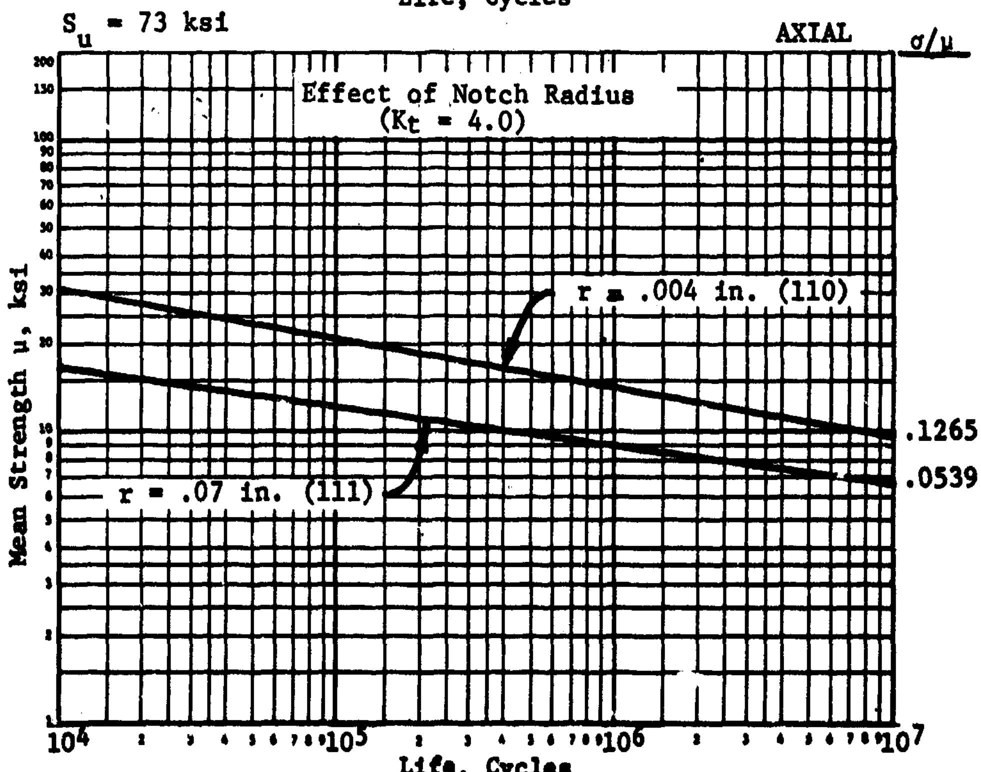


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.21

2024 ALUMINUM (SHEETS)

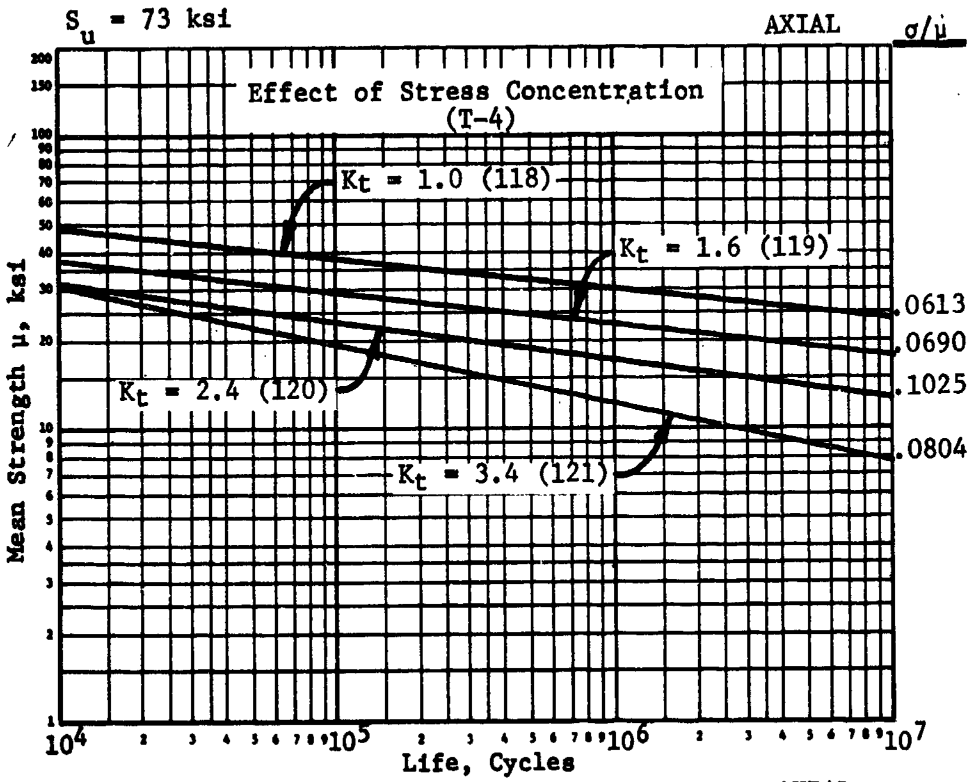


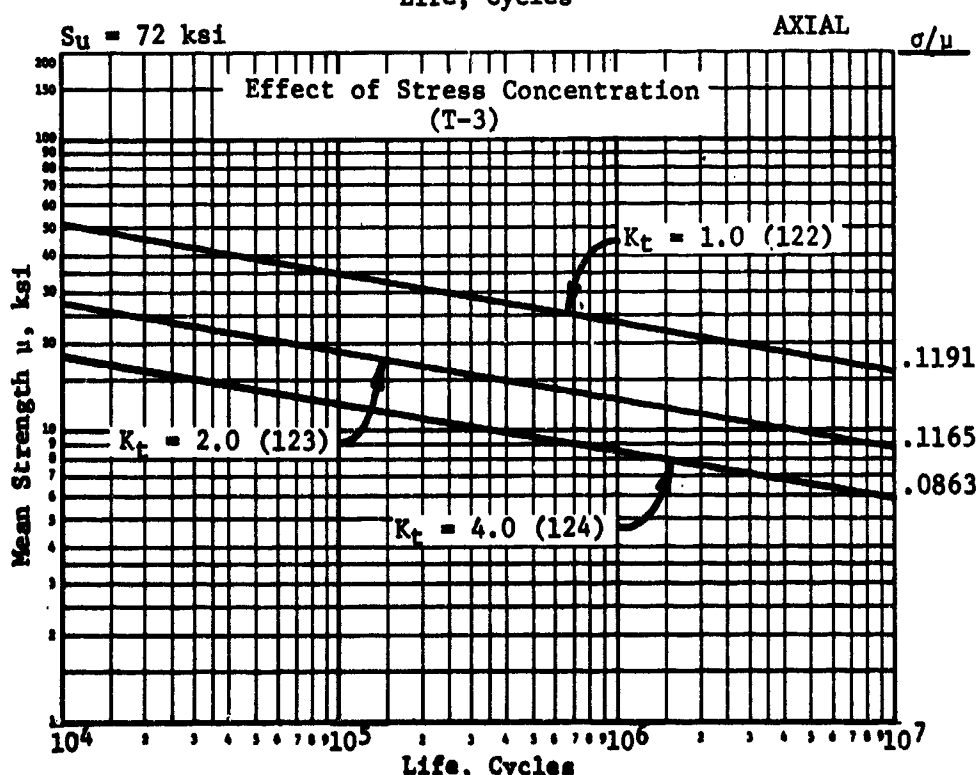


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.22

2024 ALUMINUM (BARS)

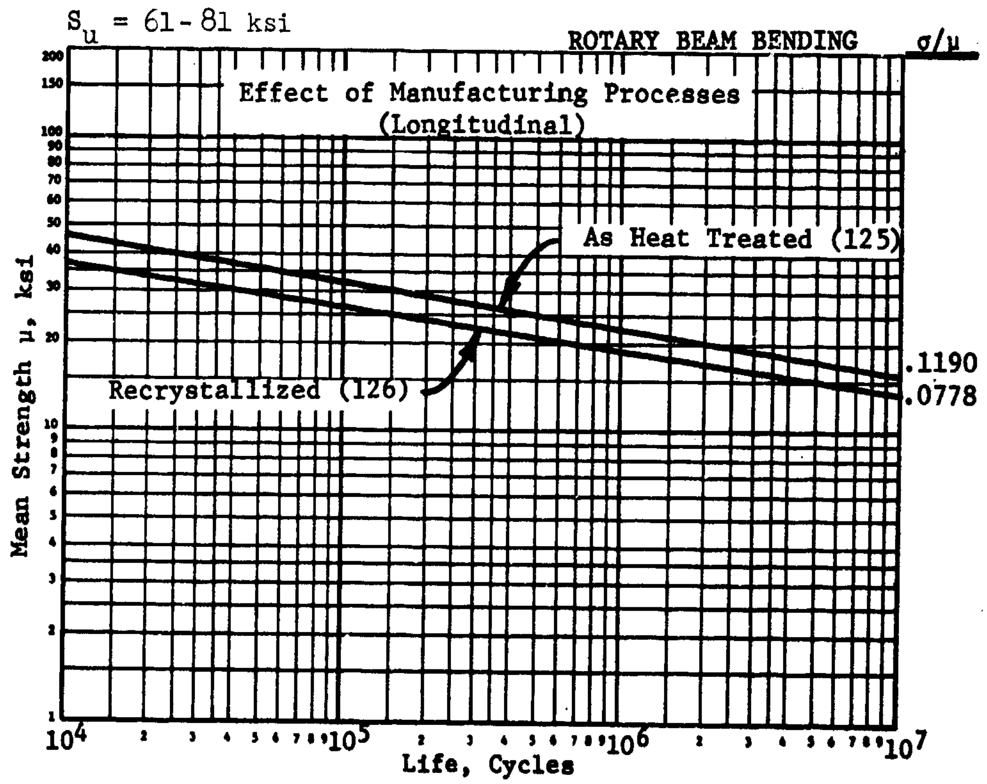




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.23

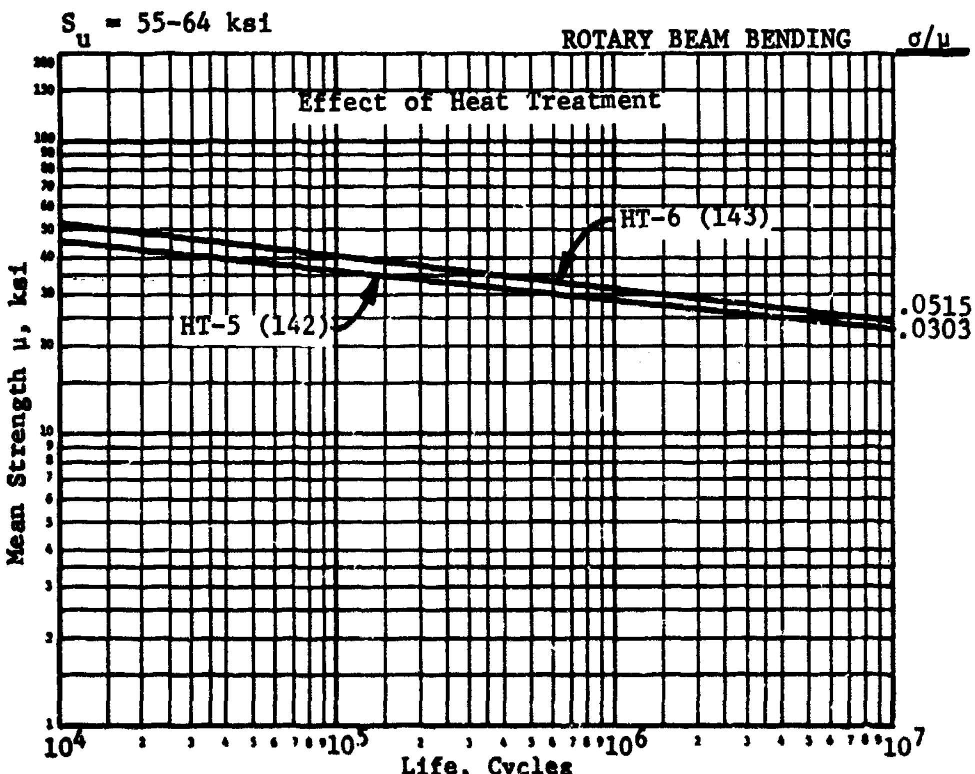
2024 ALUMINUM (EXTRUSIONS)

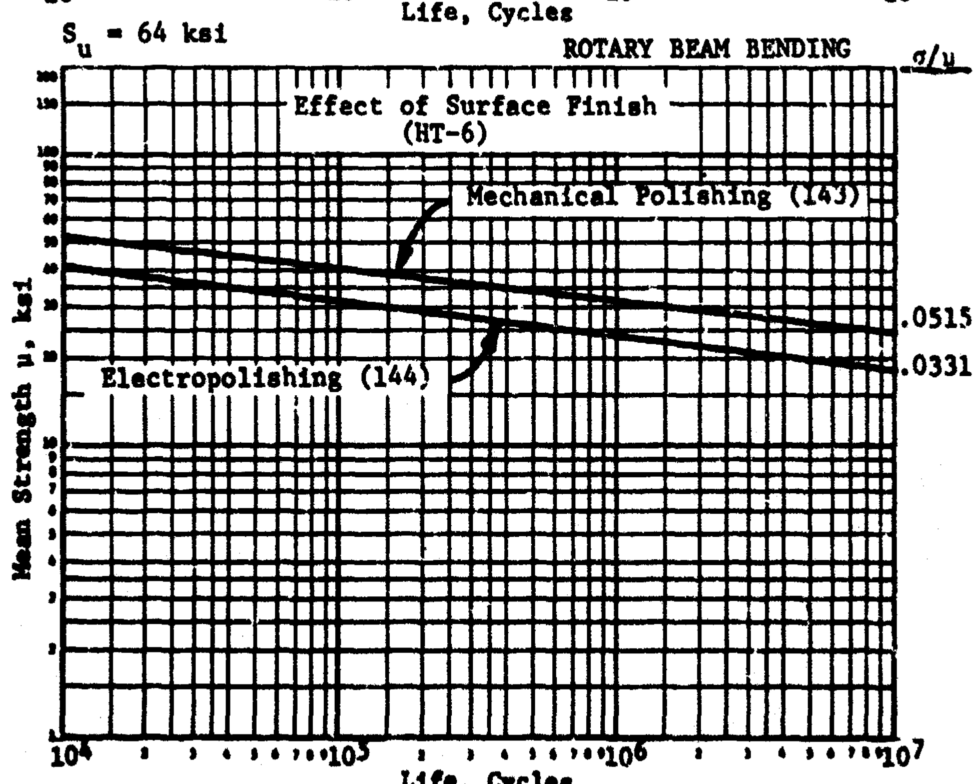


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.24

2025 ALUMINUM





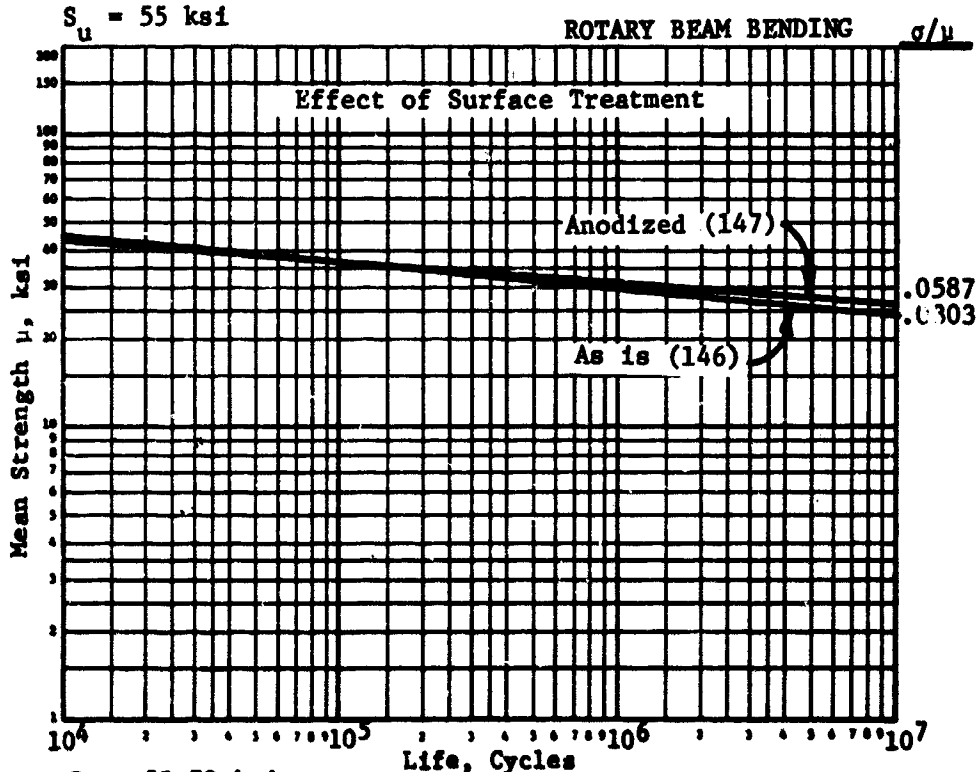
(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.25

2025 ALUMINUM

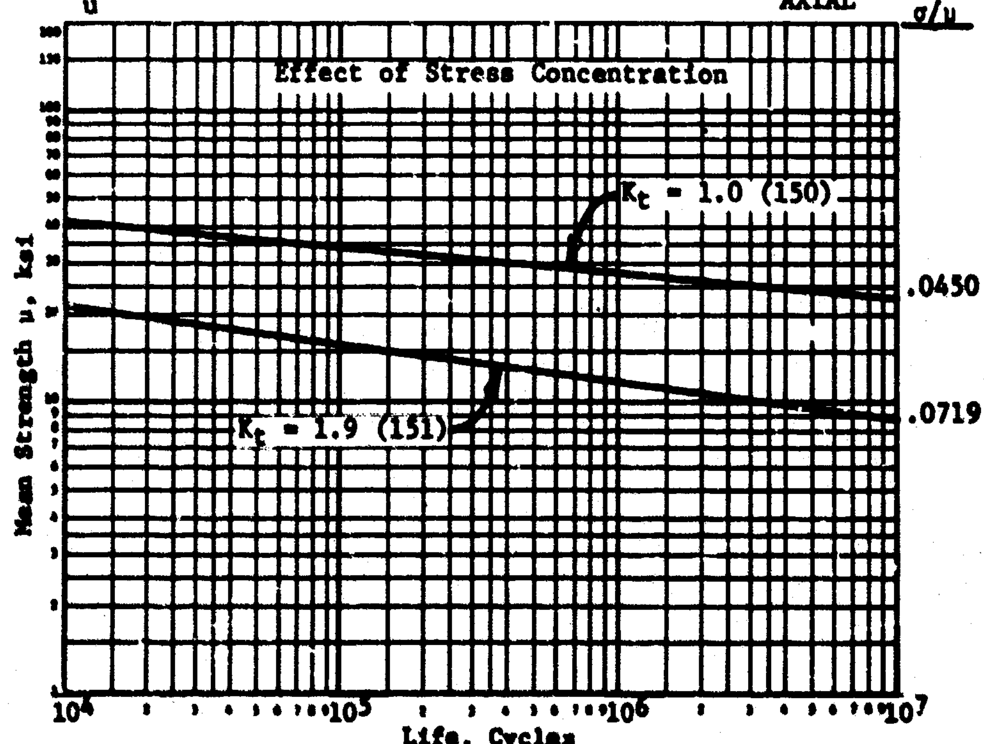
S_u = 55 ksi

ROTARY BEAM BENDING



S_u = 55-70 ksi

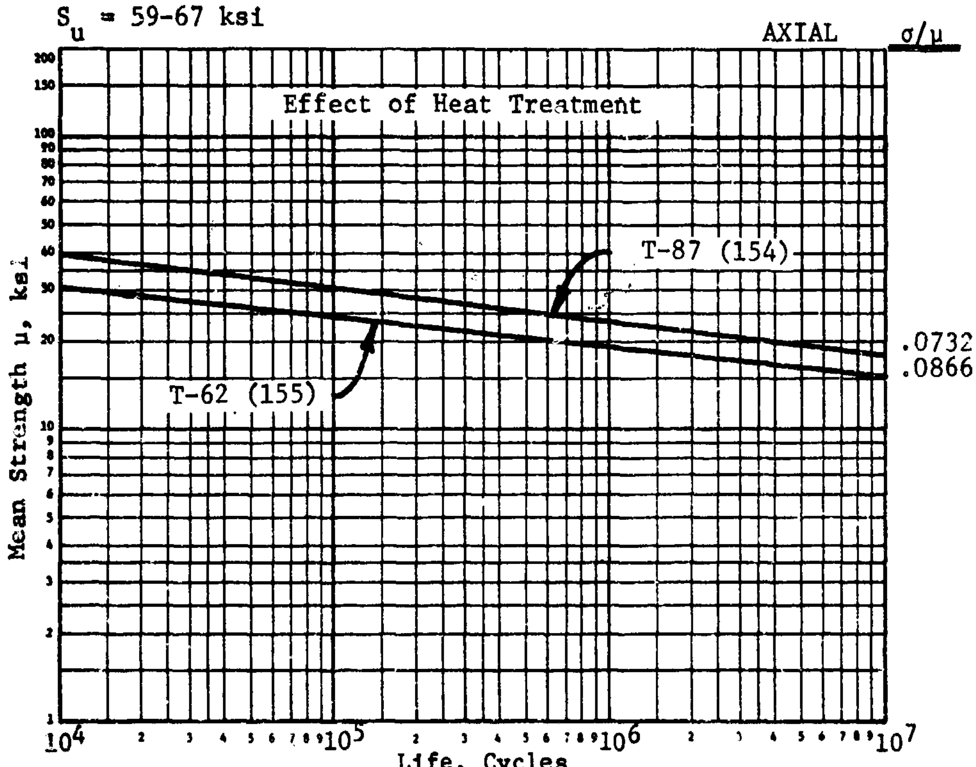
AXIAL

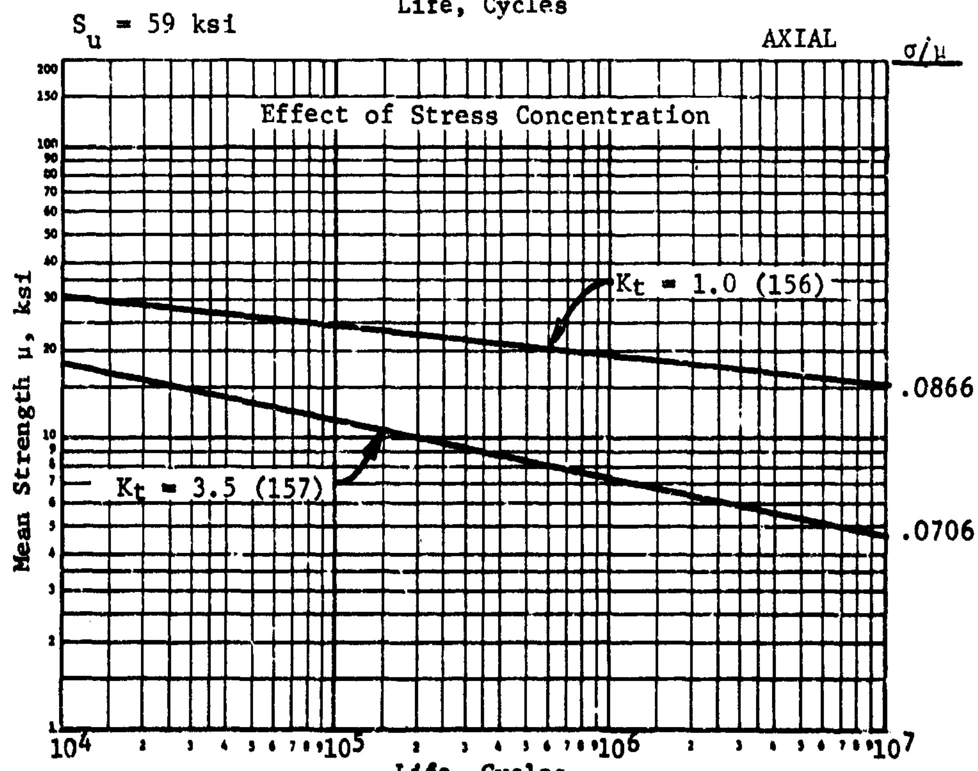


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.26

2219 ALUMINUM

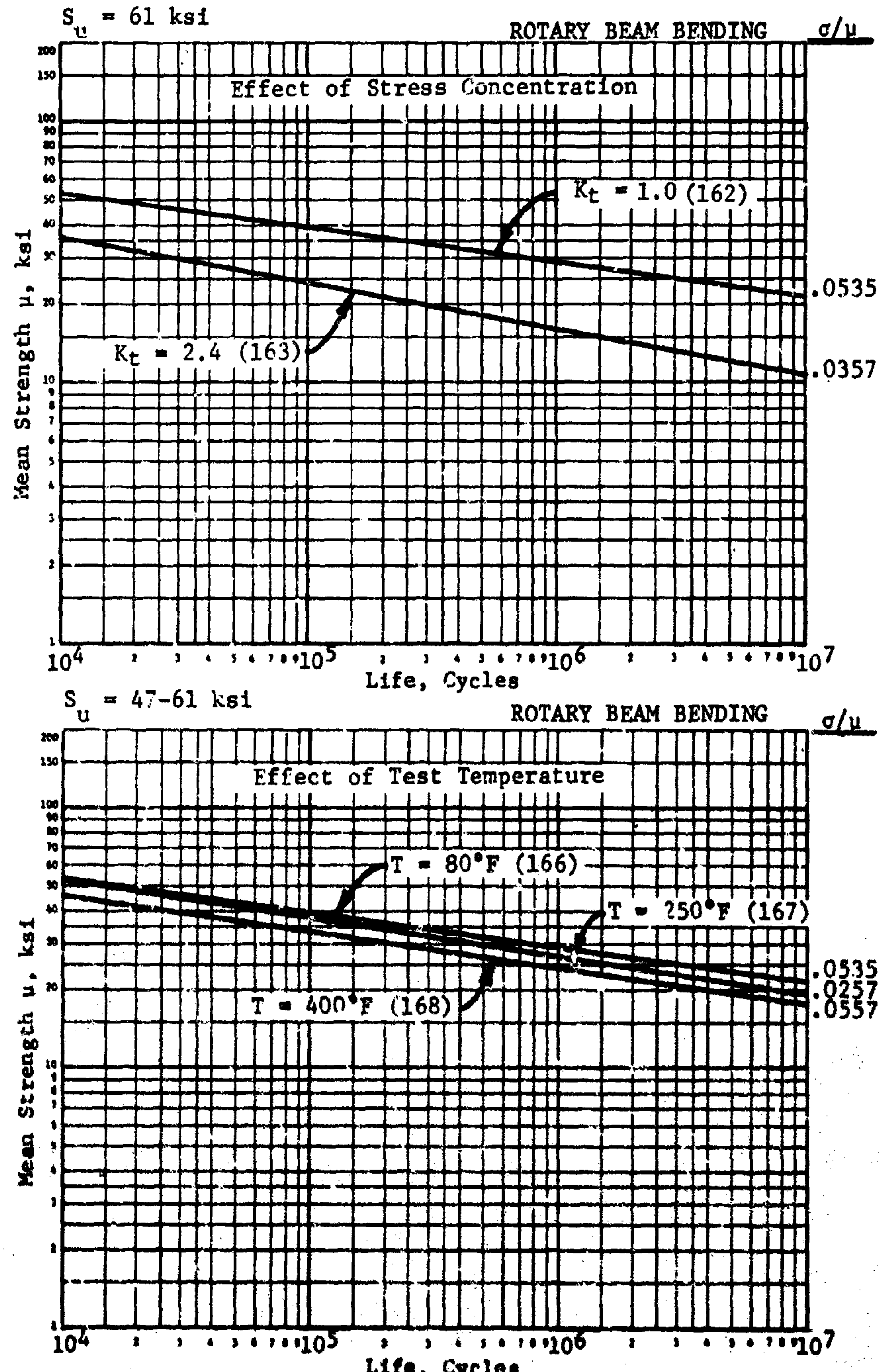




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.27

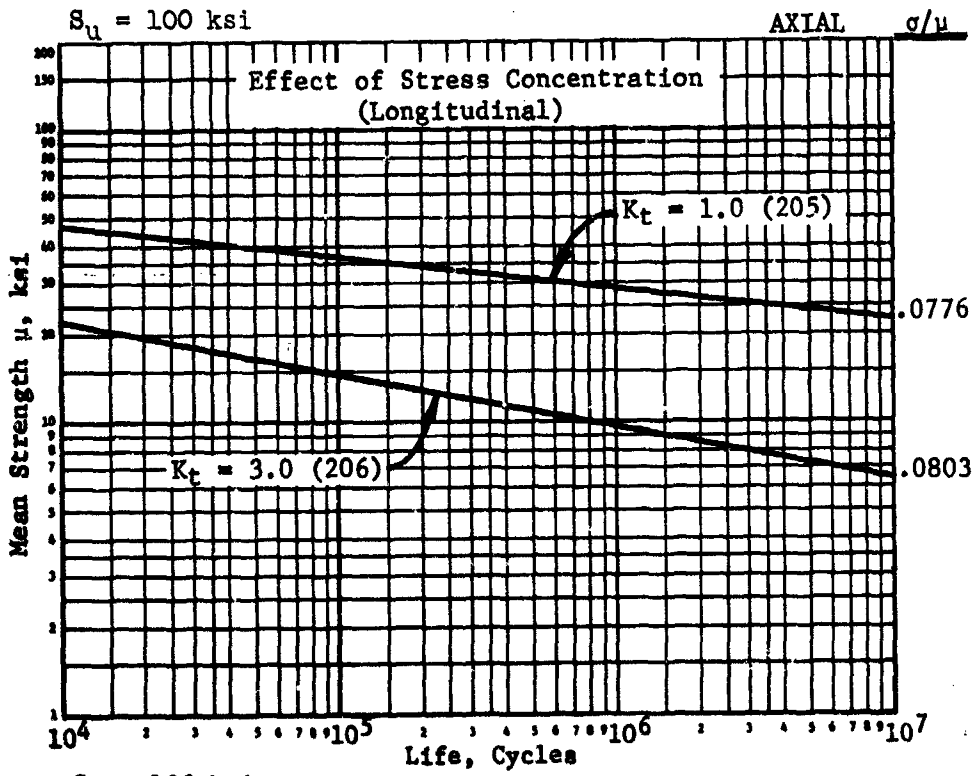
2618 ALUMINUM

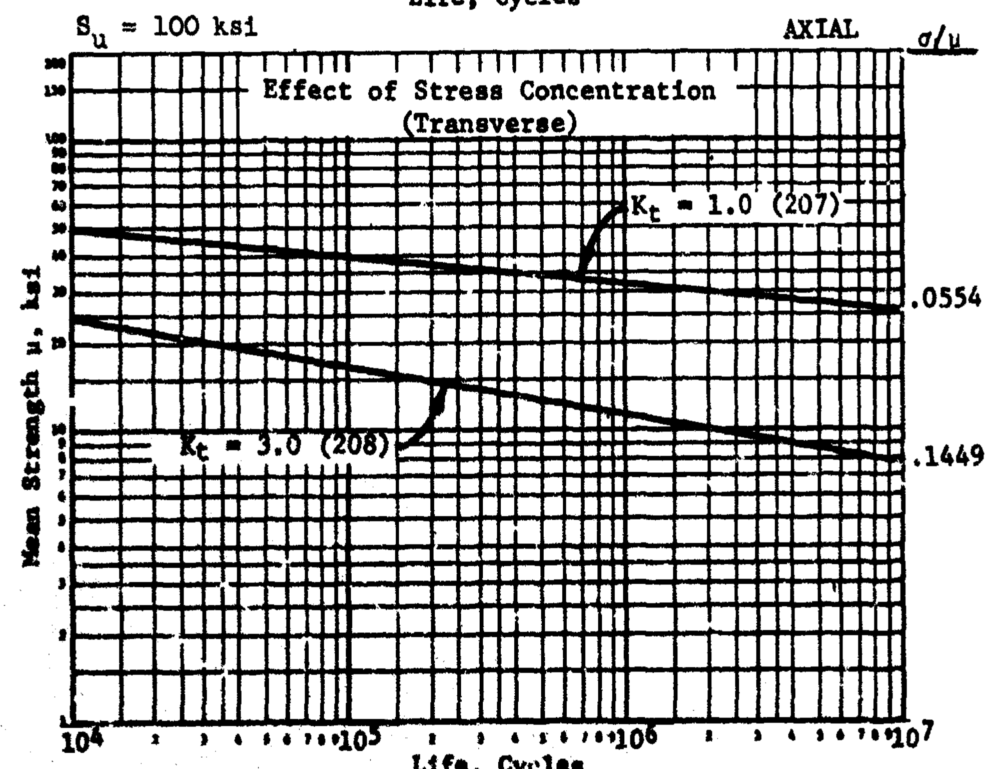


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.28

7001 ALUMINUM

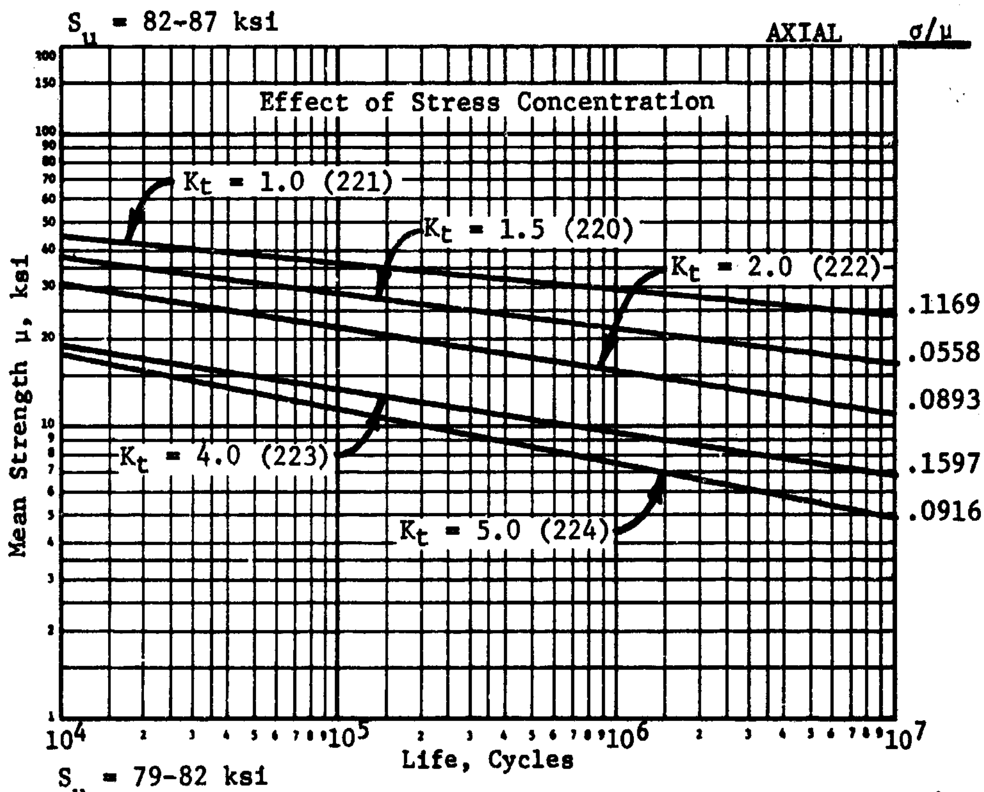


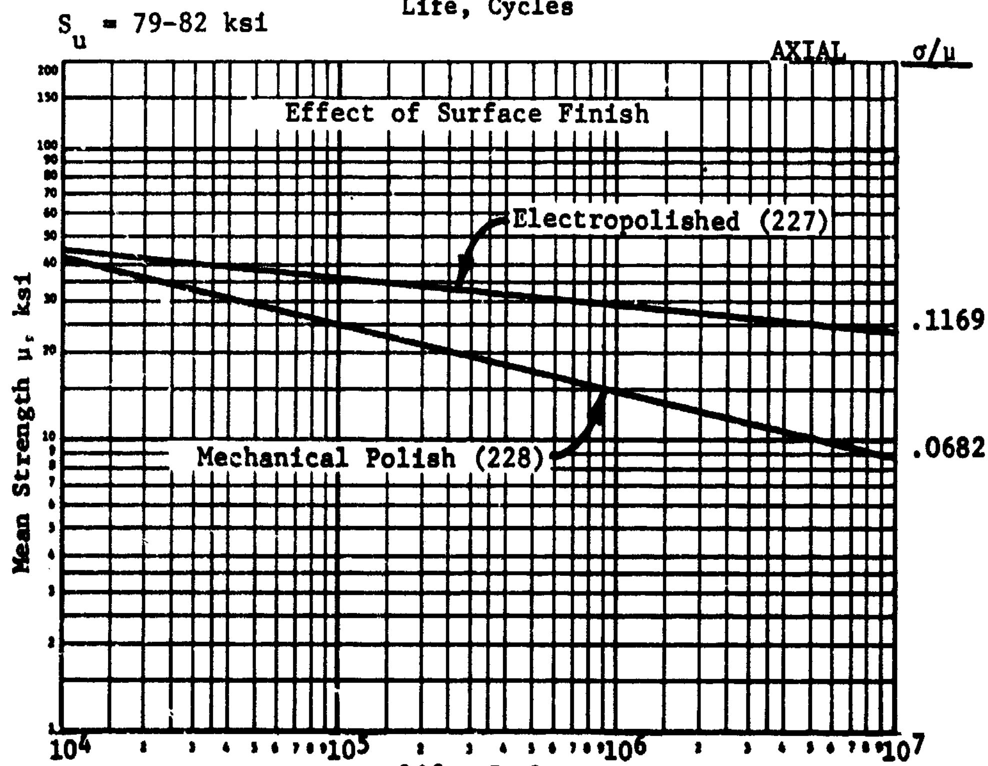


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.29

7075 ALUMINUM (SHEETS)

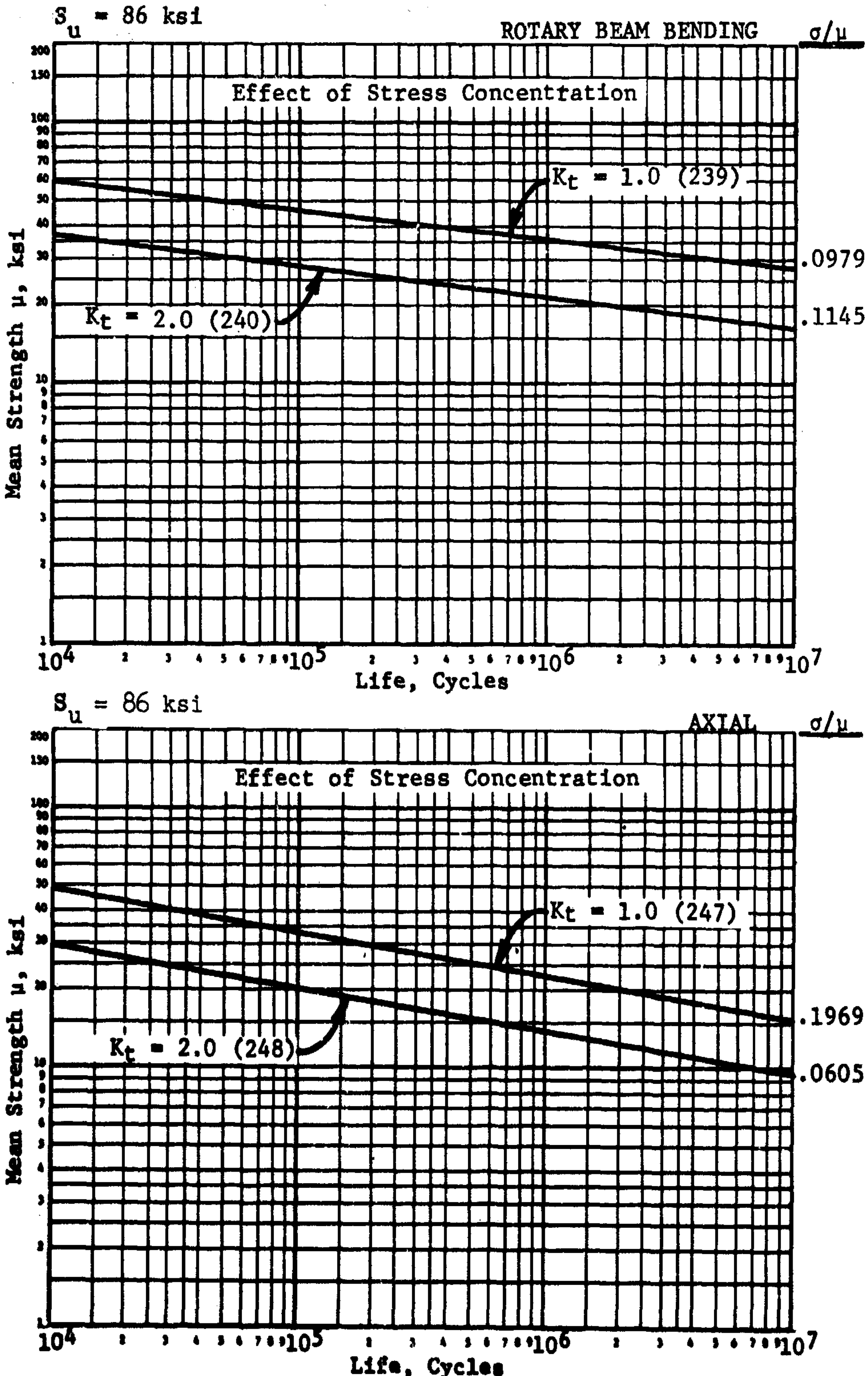




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.30

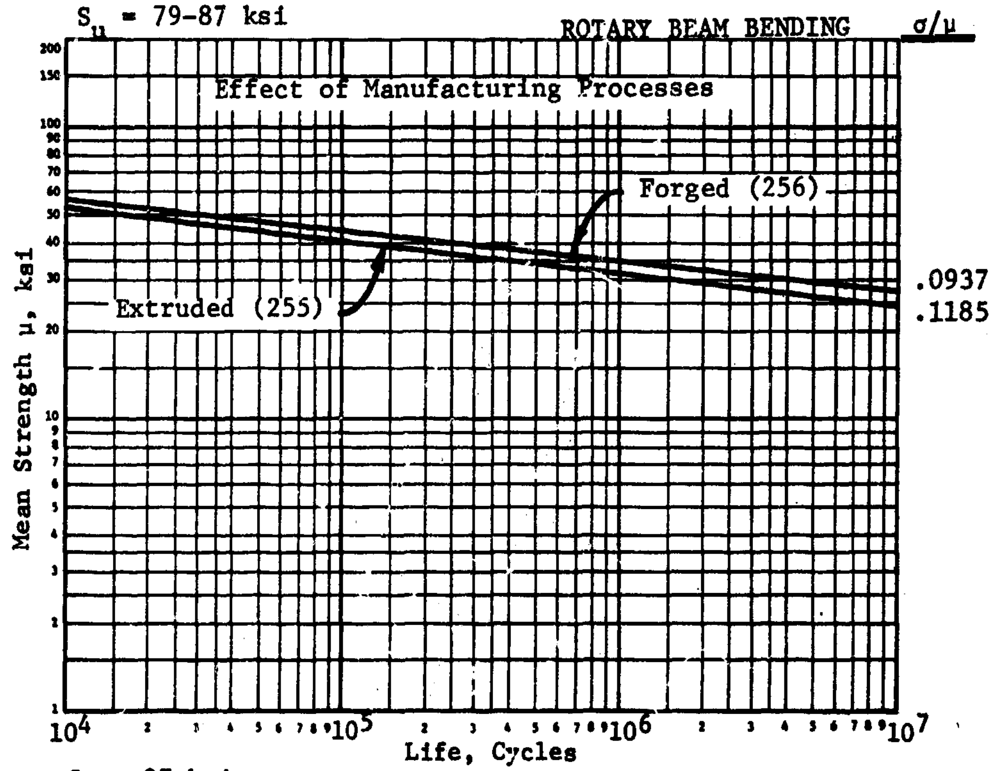
7075 ALUMINUM (BAR)

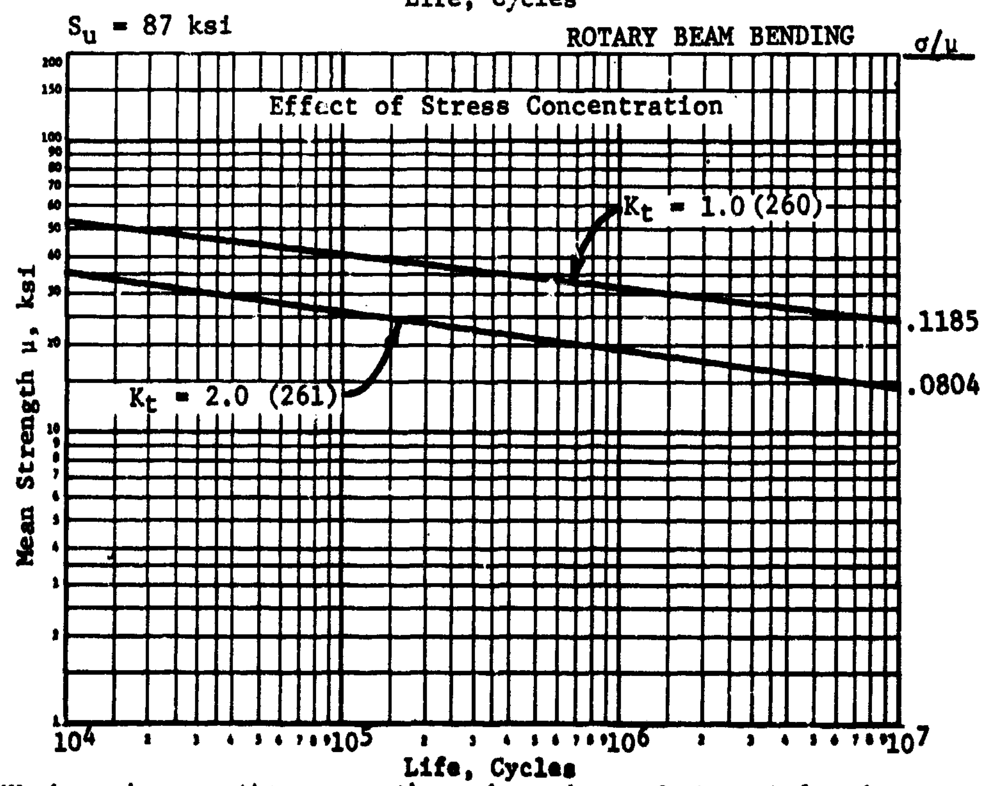


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.31

7075 ALUMINUM
EXTRUSIONS AND FORGINGS

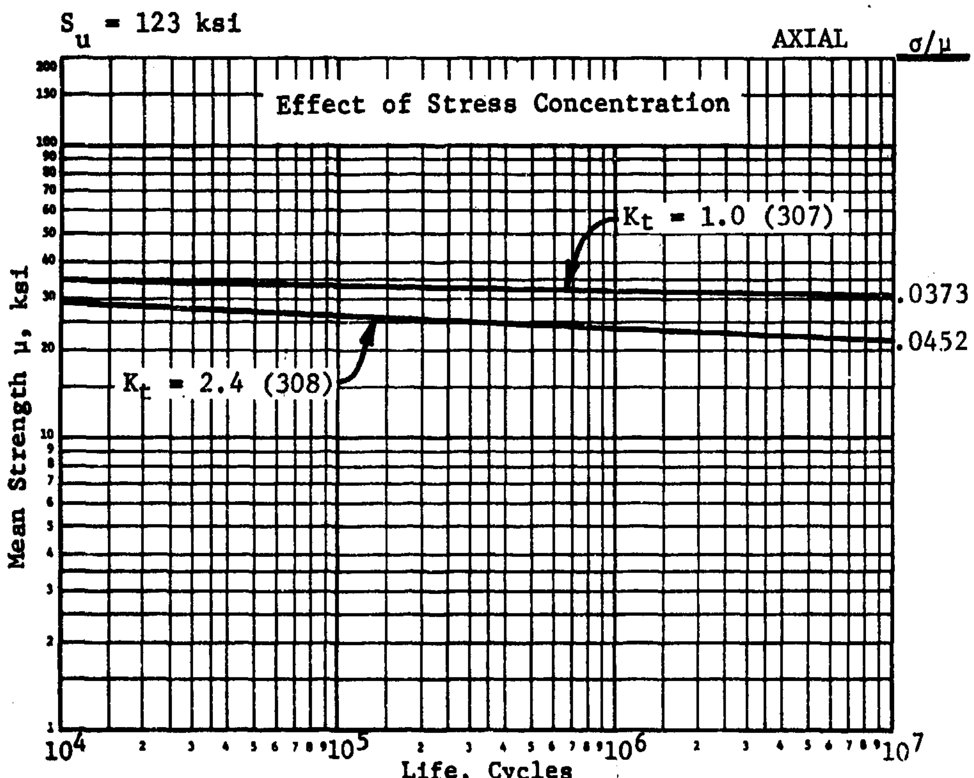


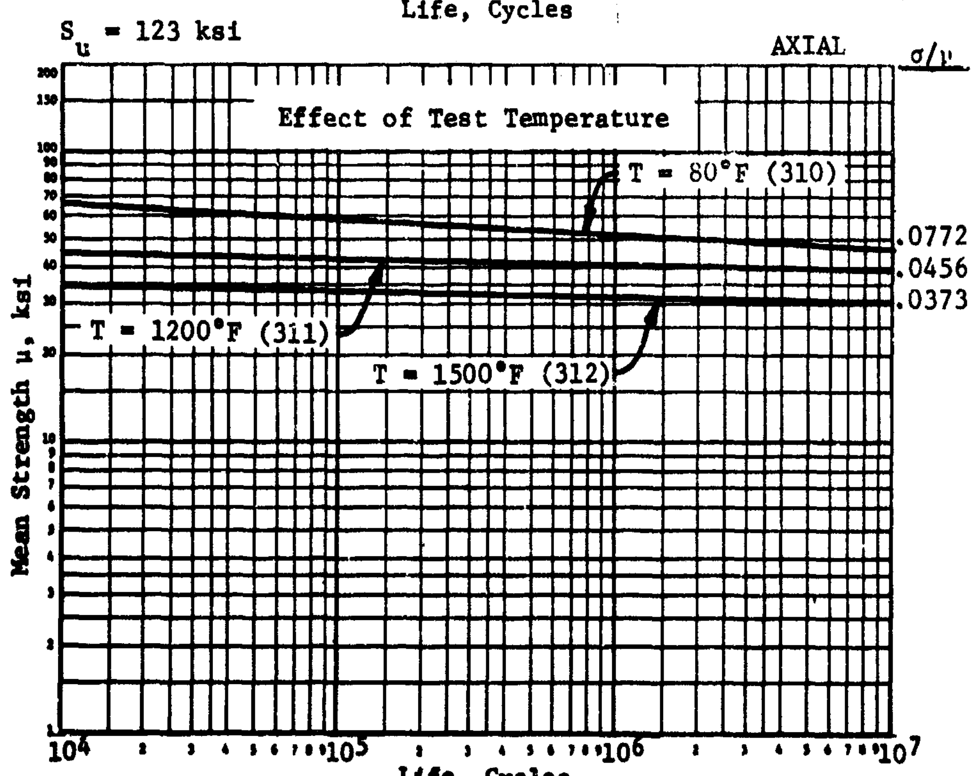


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.32

STELLITE - 31

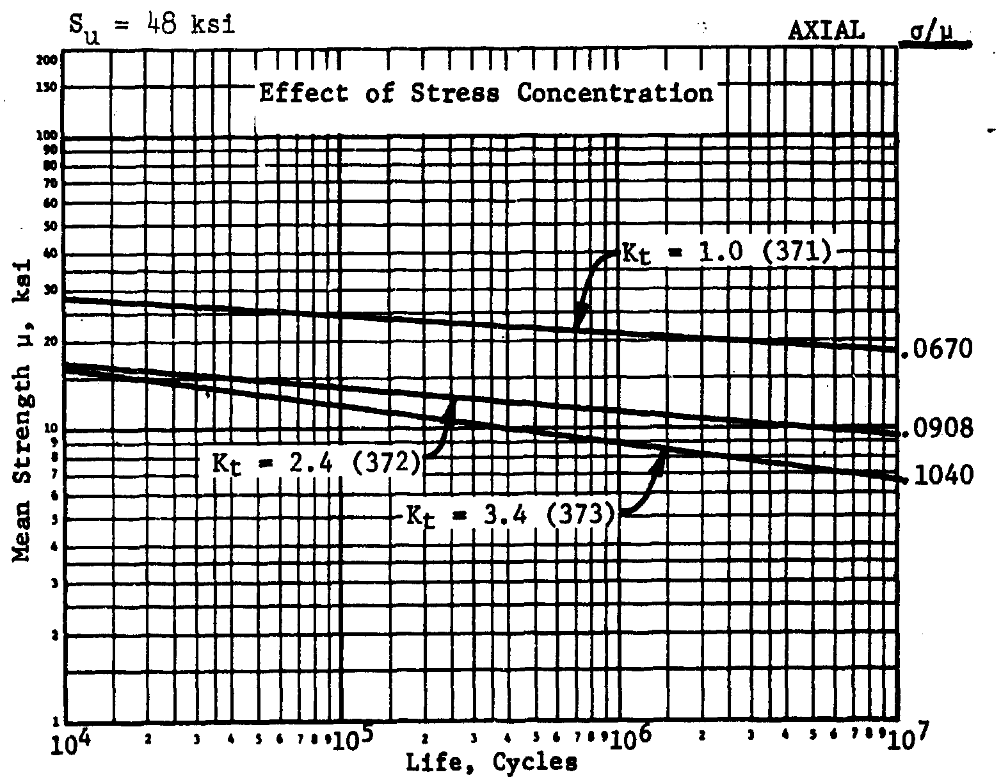




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.33

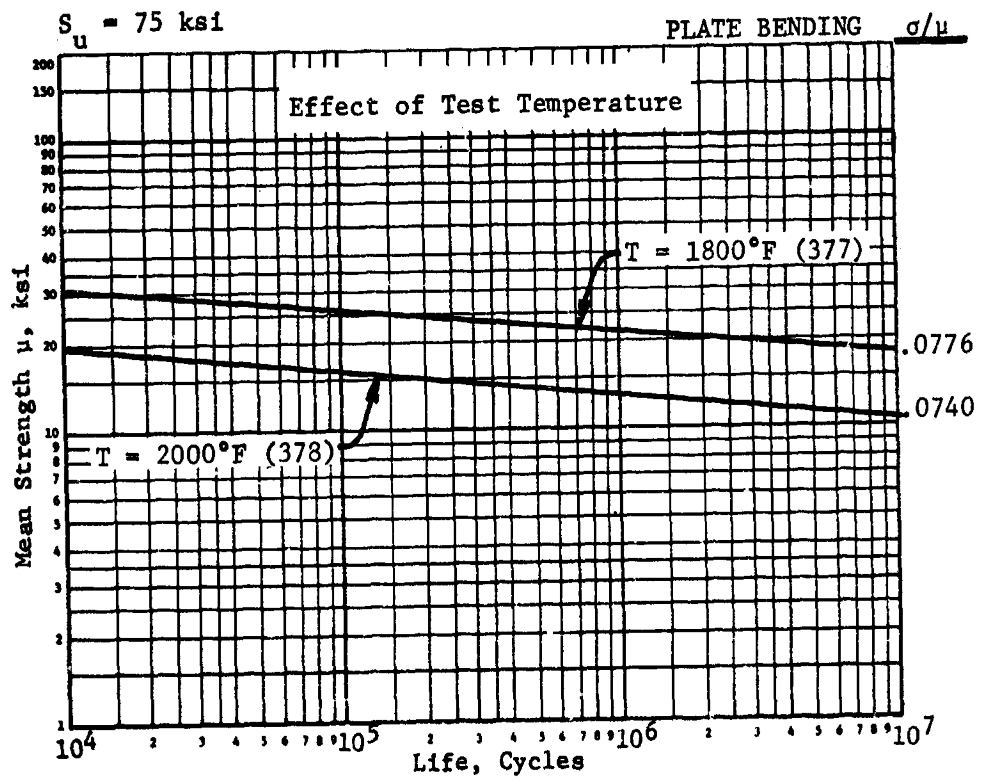
ZK60A MAGNESIUM



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.34

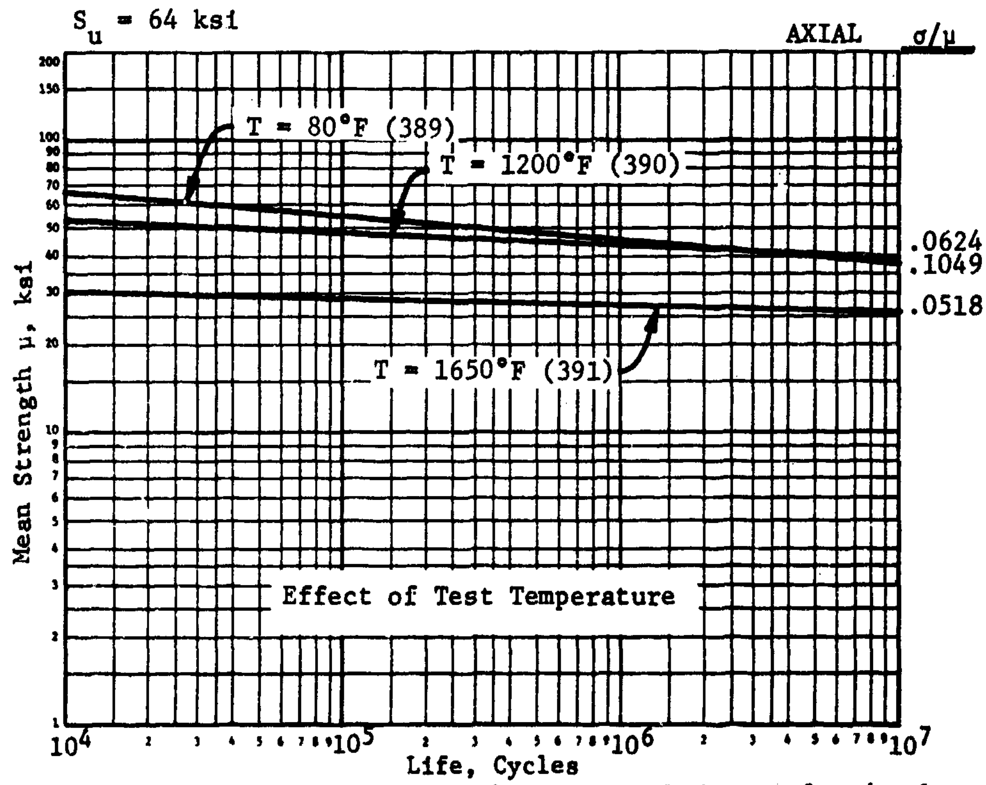
FS-27 NICKEL



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.35

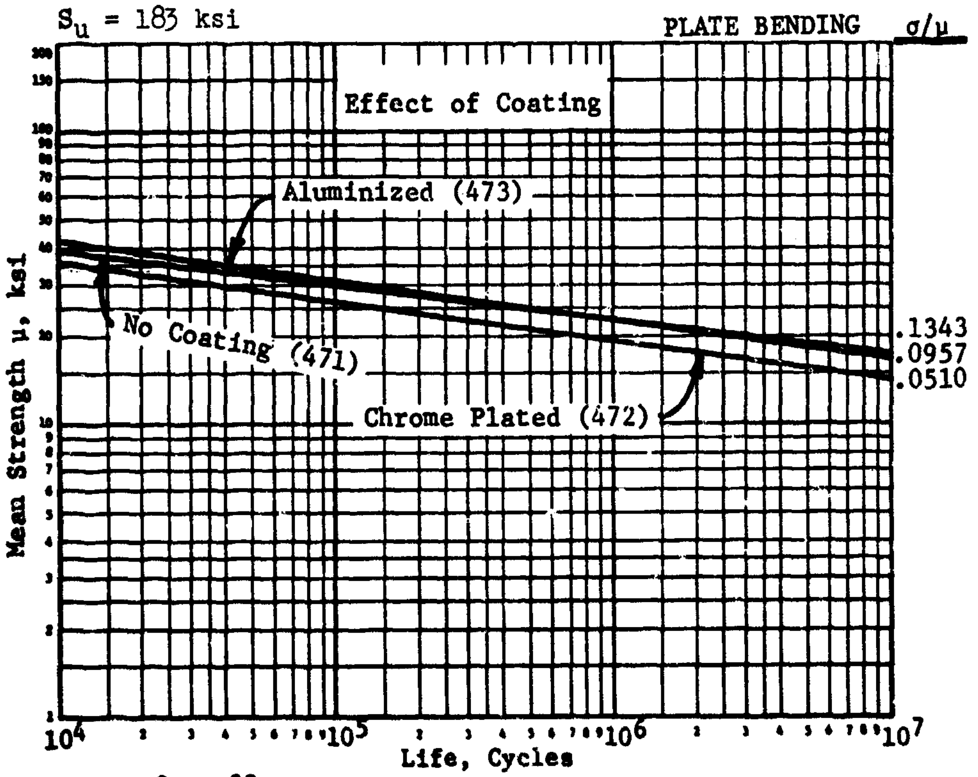
HASTELLOY - R235

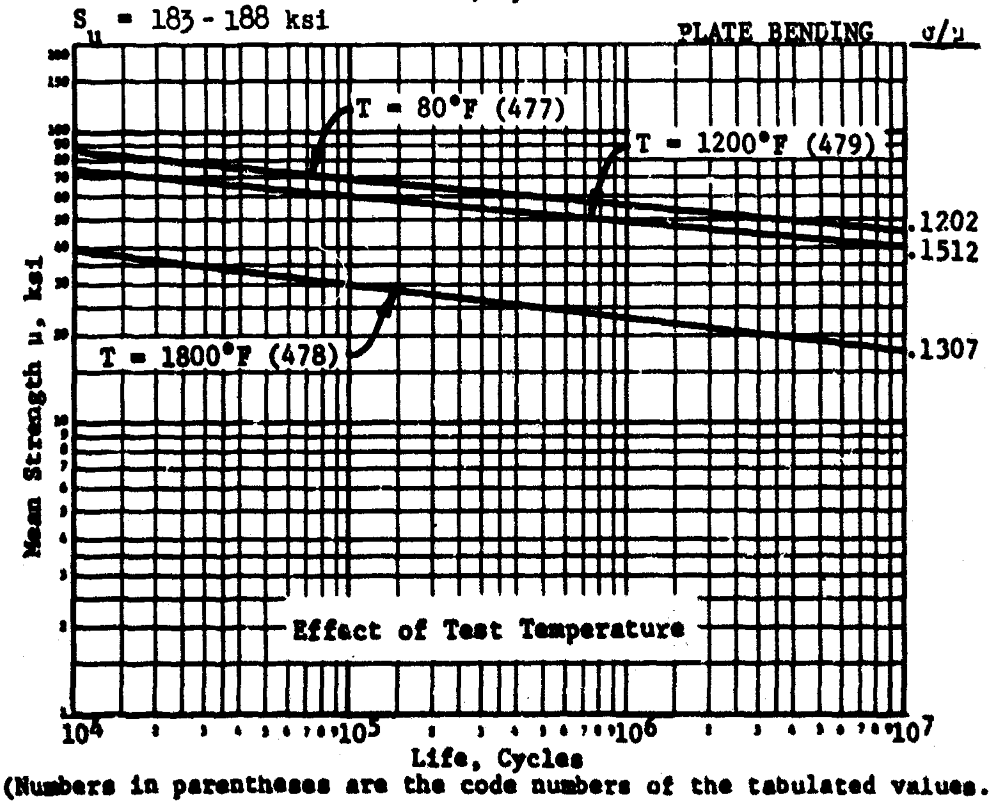


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.36

UDIMET - 500

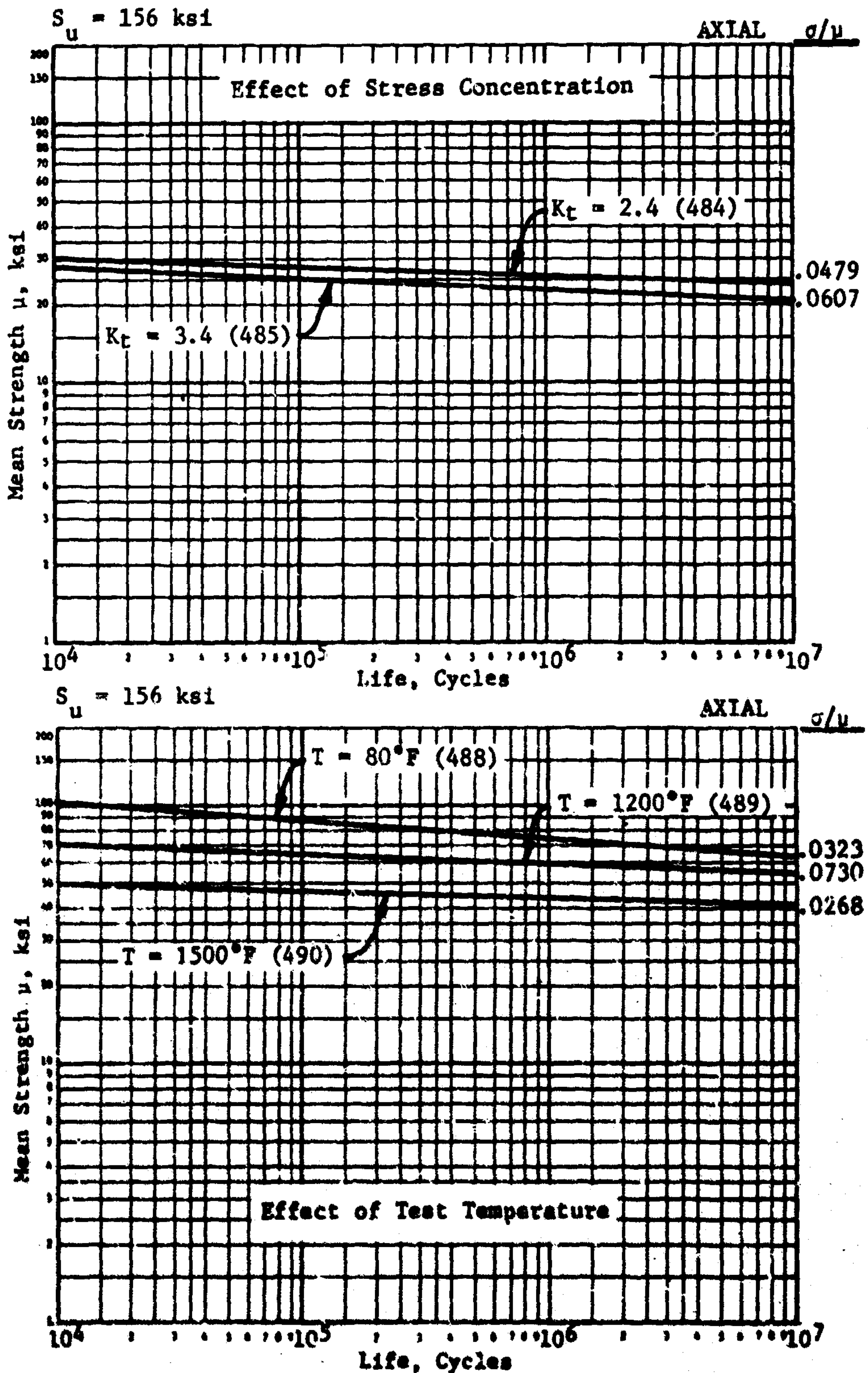




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.37

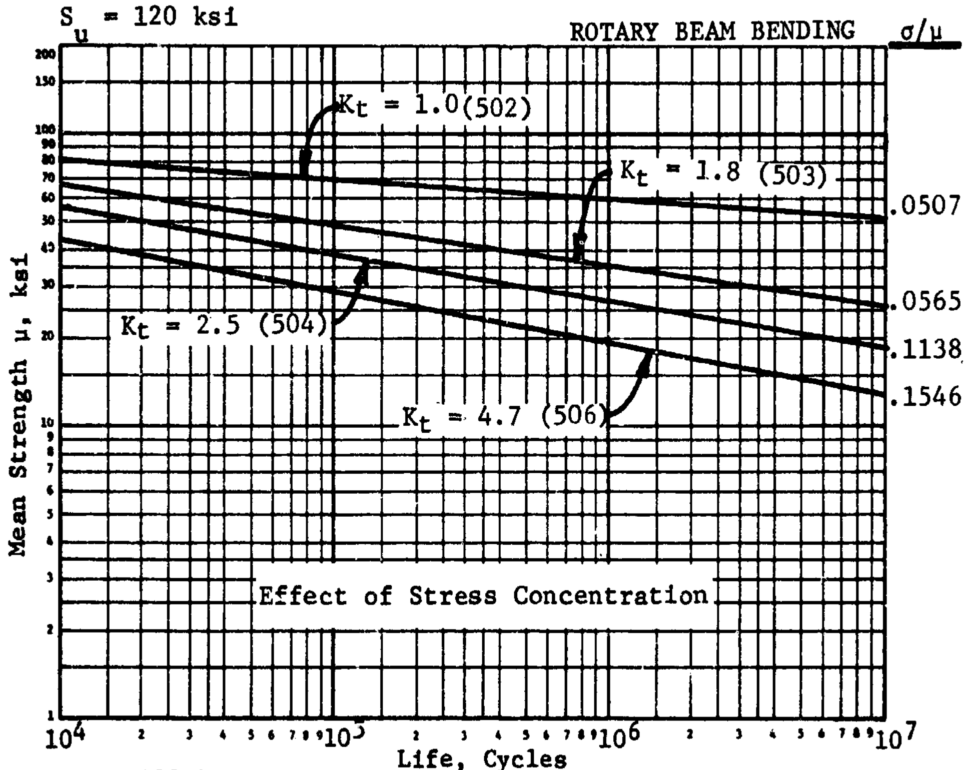
6 Mo WASPALLOY

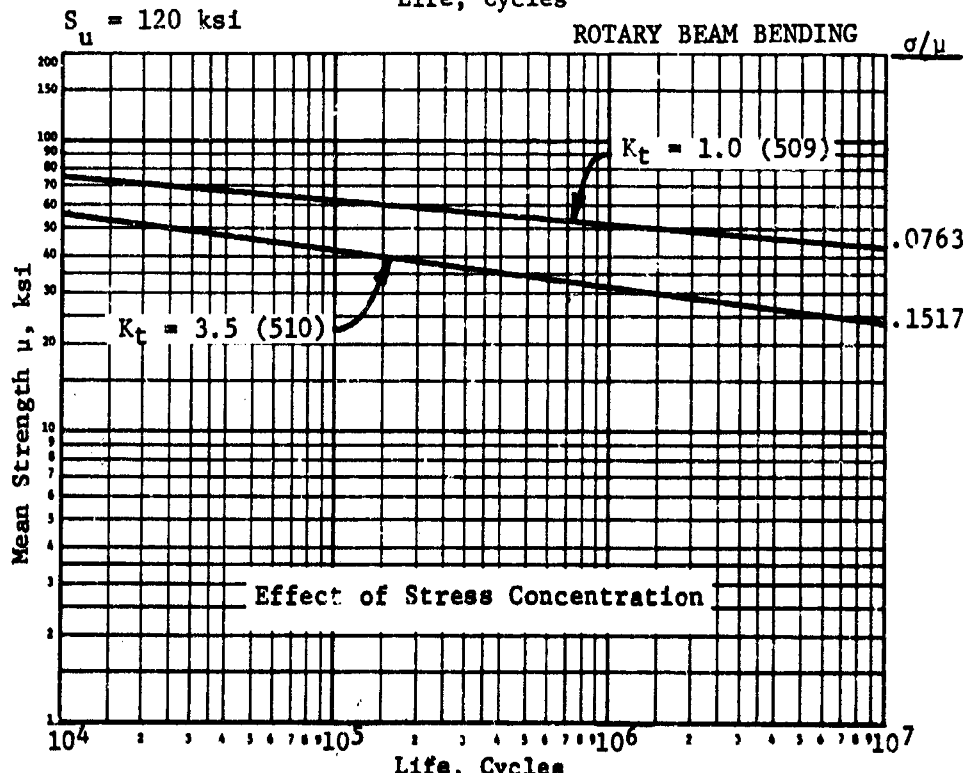


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.38

Ti - A55

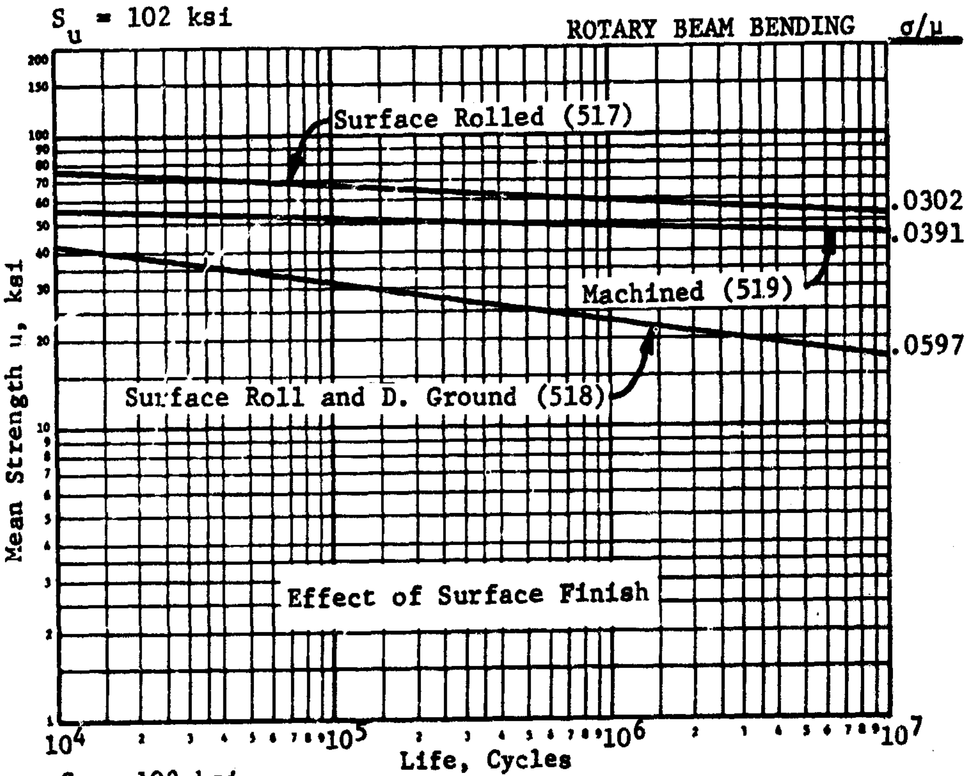


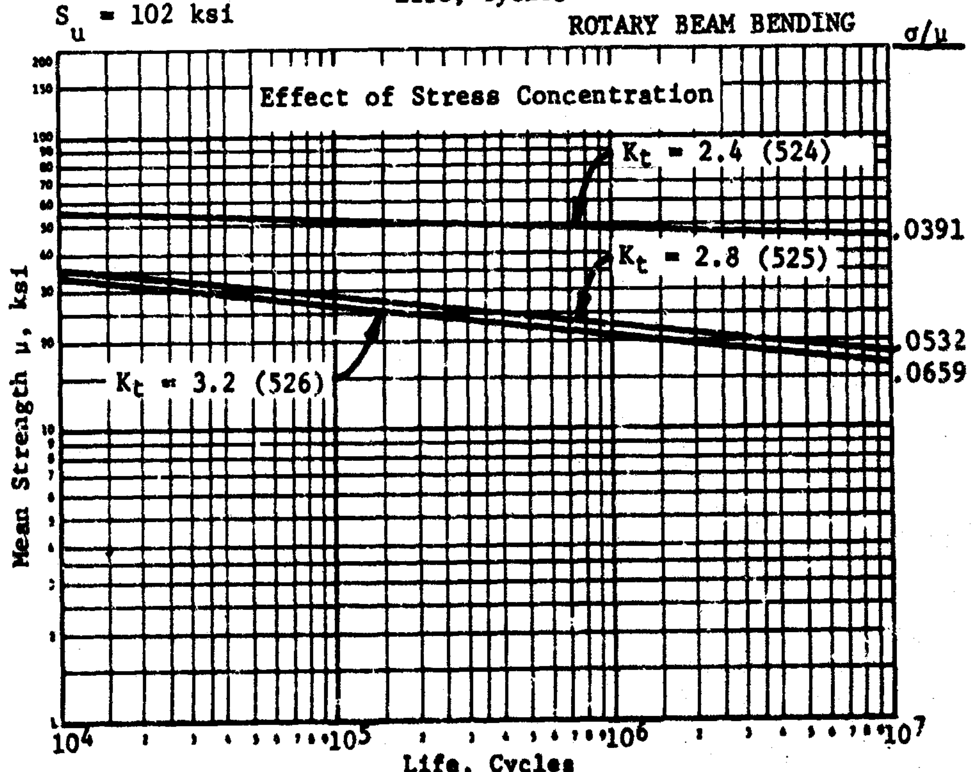


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.39

Ti - 75A

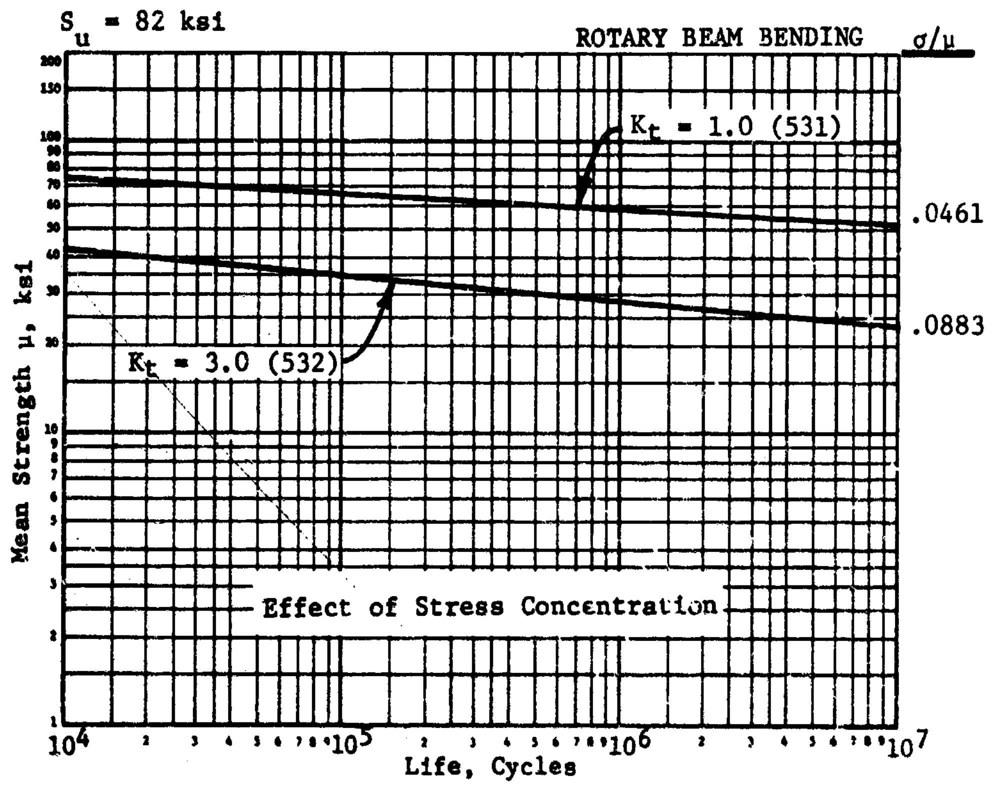




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.40

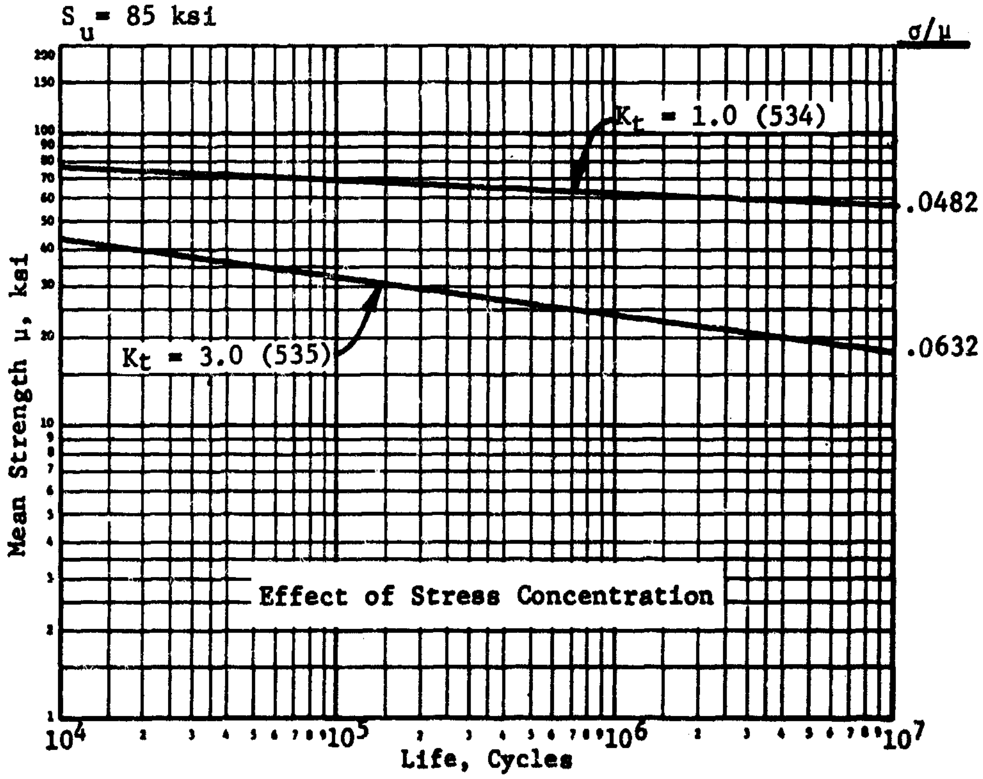
$Ti - 0.2\ O_2$



(Numbers in parentheses are the code numbers of the tabulated values.)

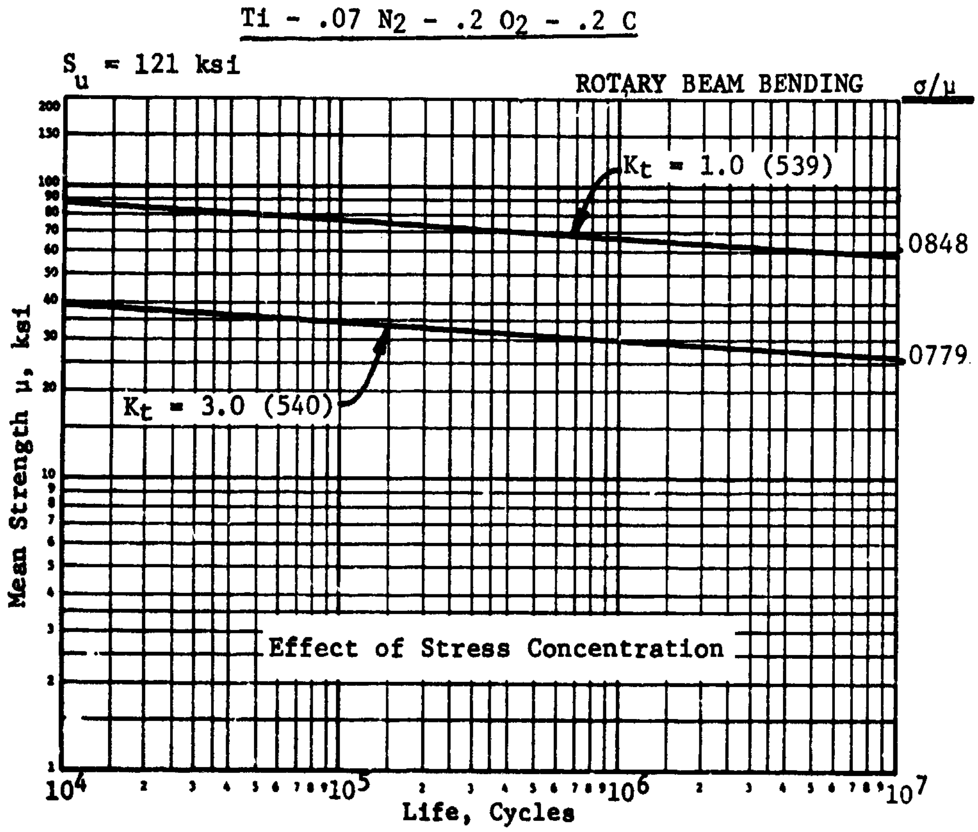
Figure 6.41

Ti - 0.2 C



(Numbers in parentheses are the code numbers of the tabulated values.)

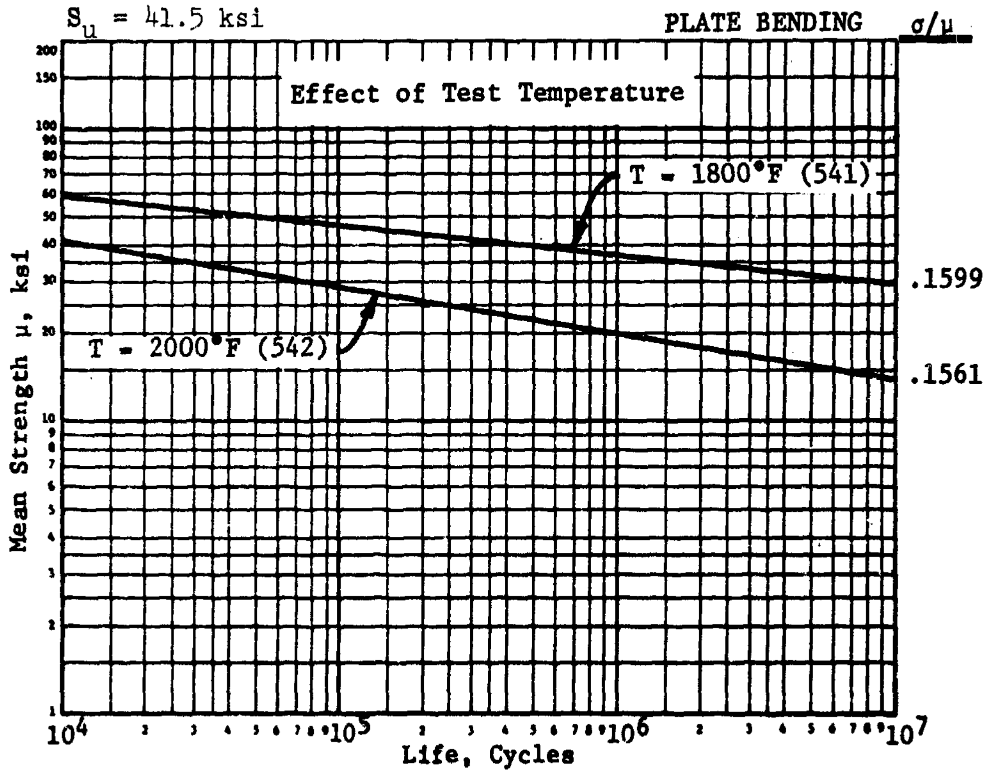
Figure 6.42



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.43

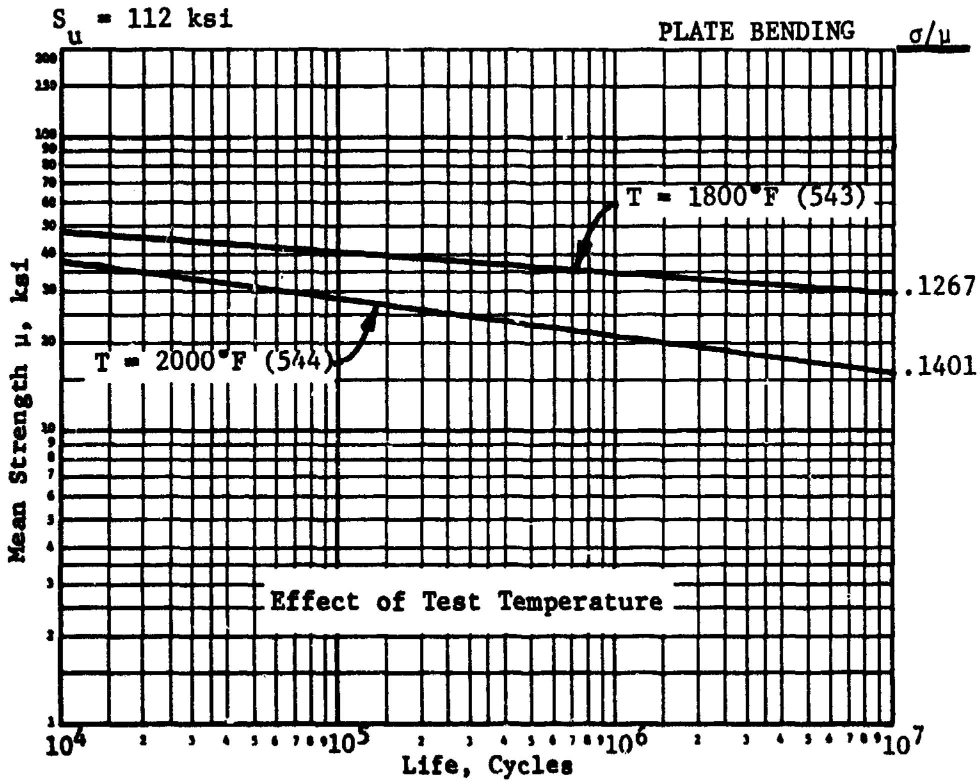
K-151A CERMET



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.44

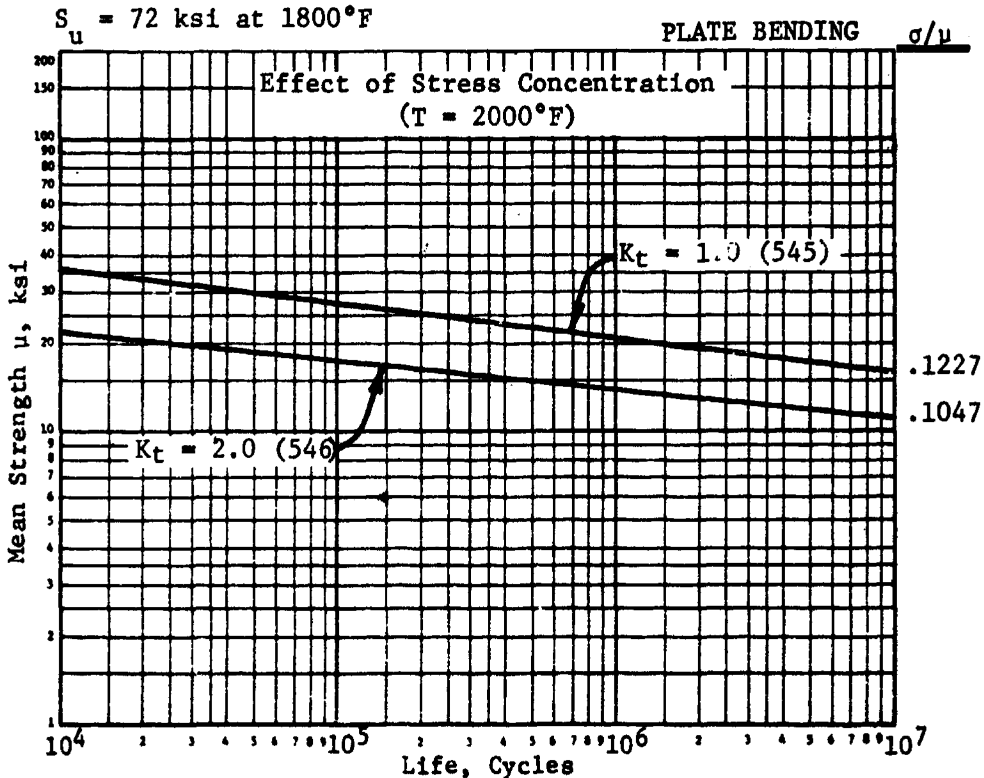
K-162B CERMET

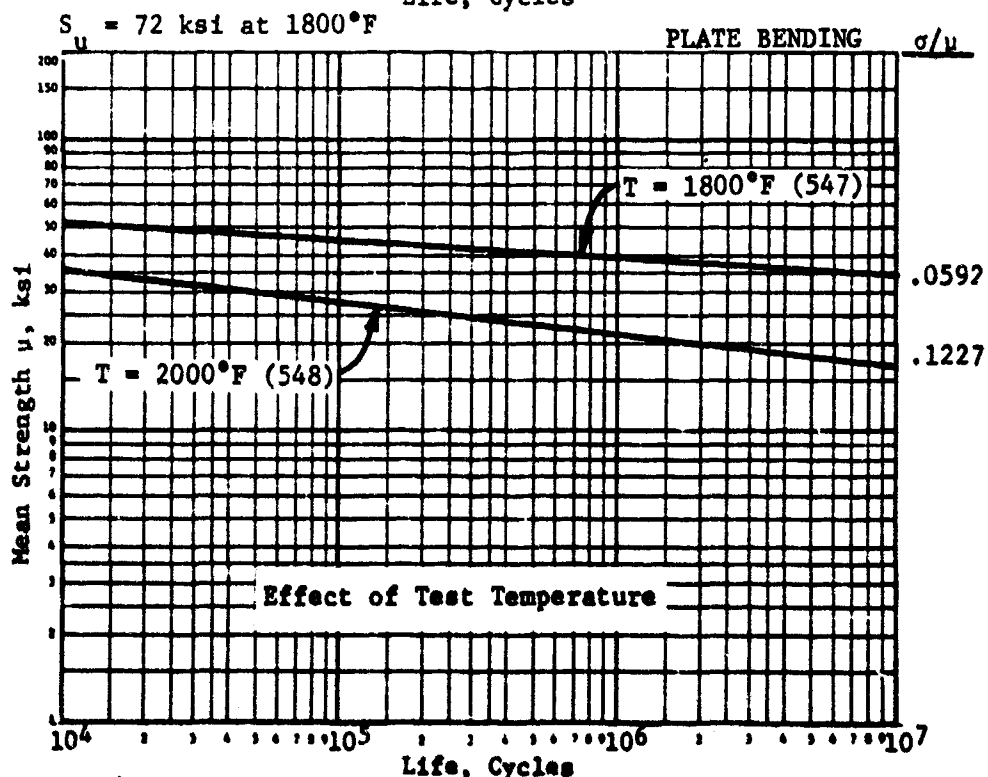


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.45

K-183A CERMET

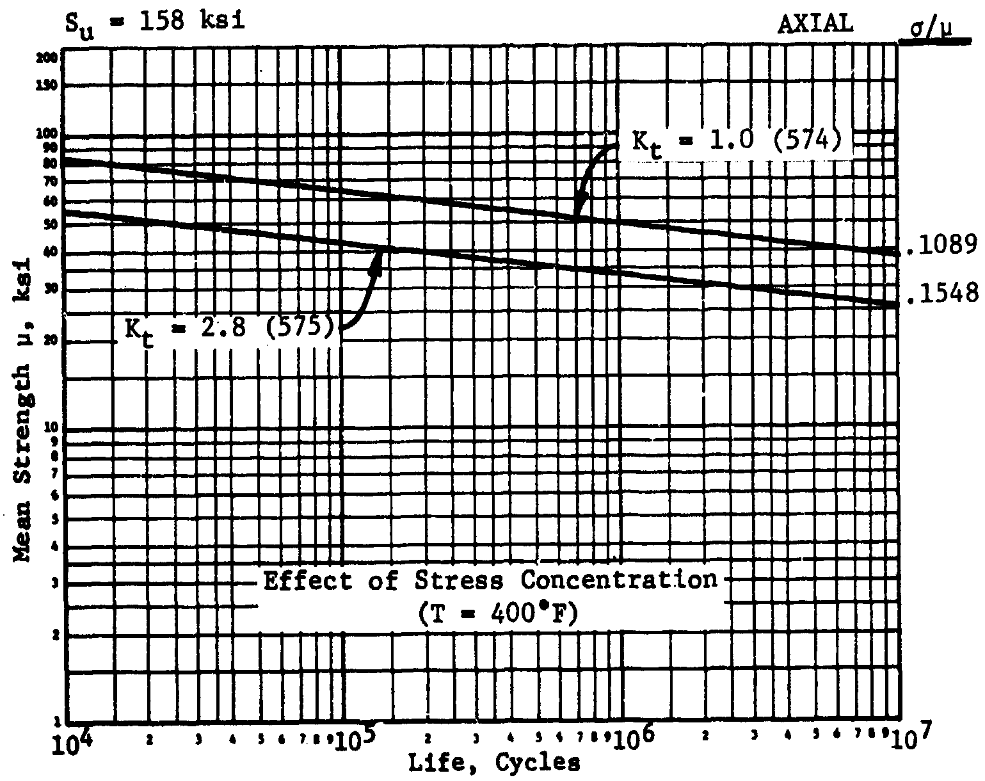


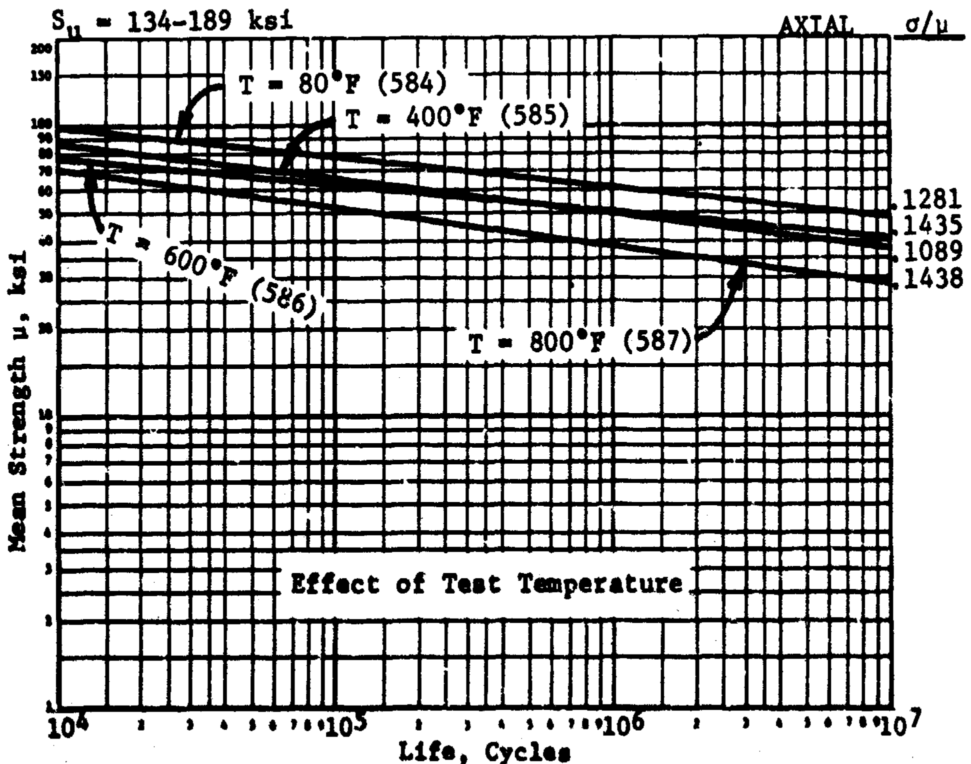


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.46

Ti - 4 Al - 3 Mo - 1 V

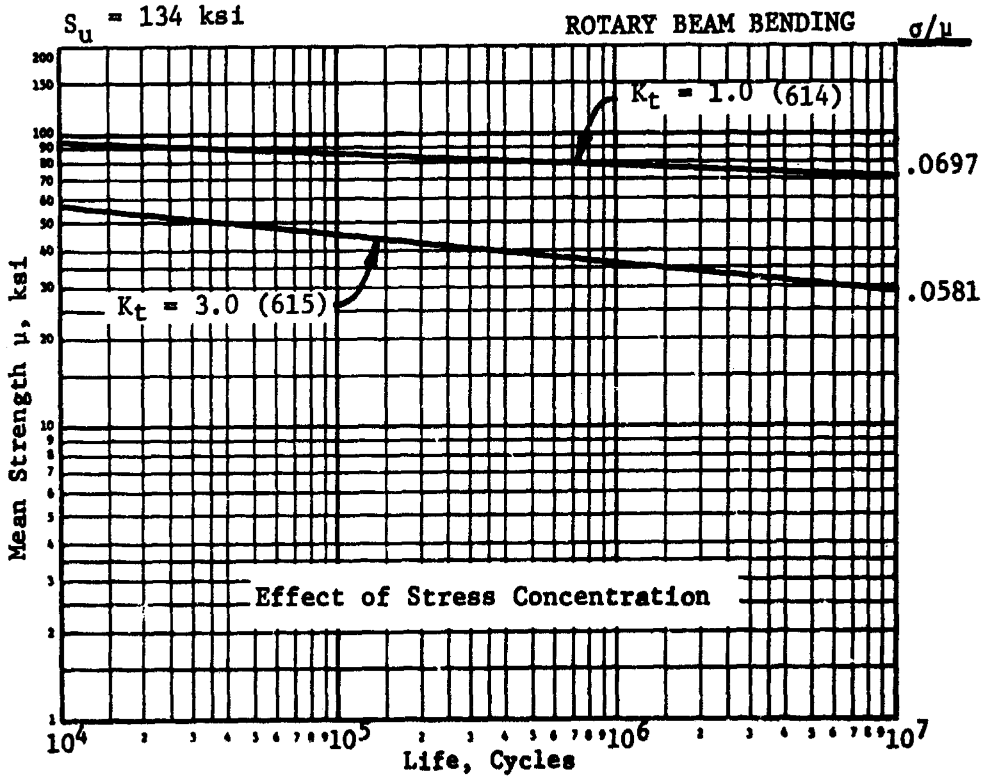




(Numbers in parentheses are the code numbers of the tabulated values.)

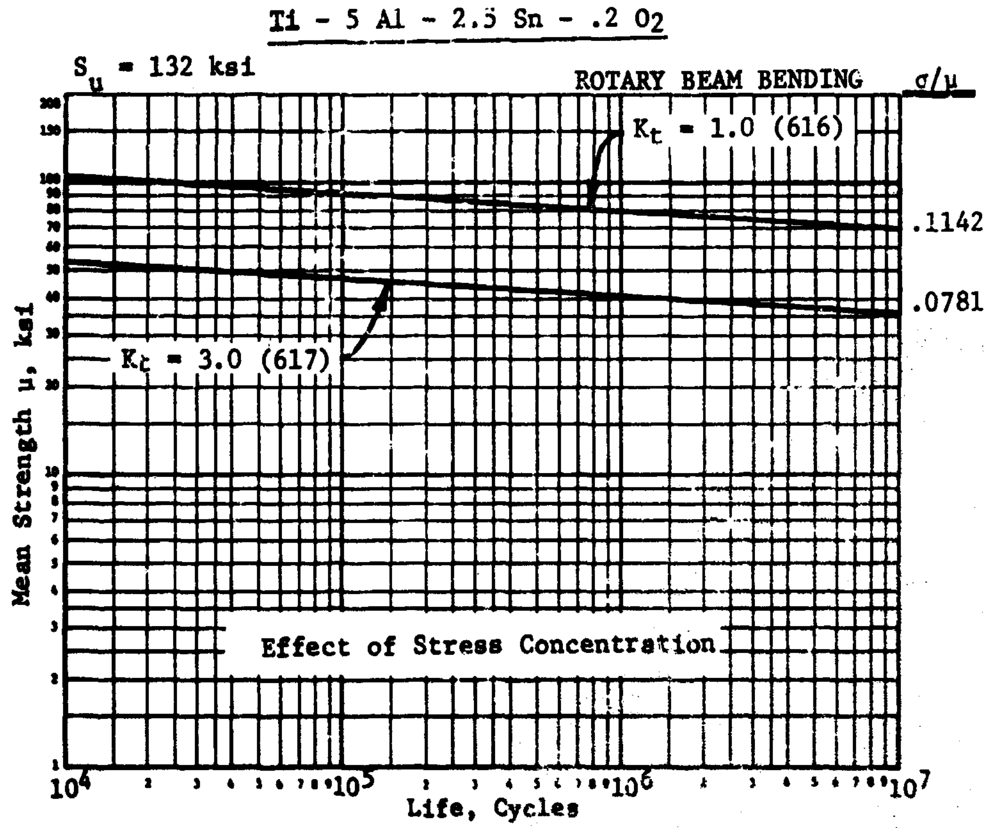
Figure 6.47

Ti - 5 Al - 2.5 Sn - .07 N_2



(Numbers in parentheses are the code numbers of the tabulated values.)

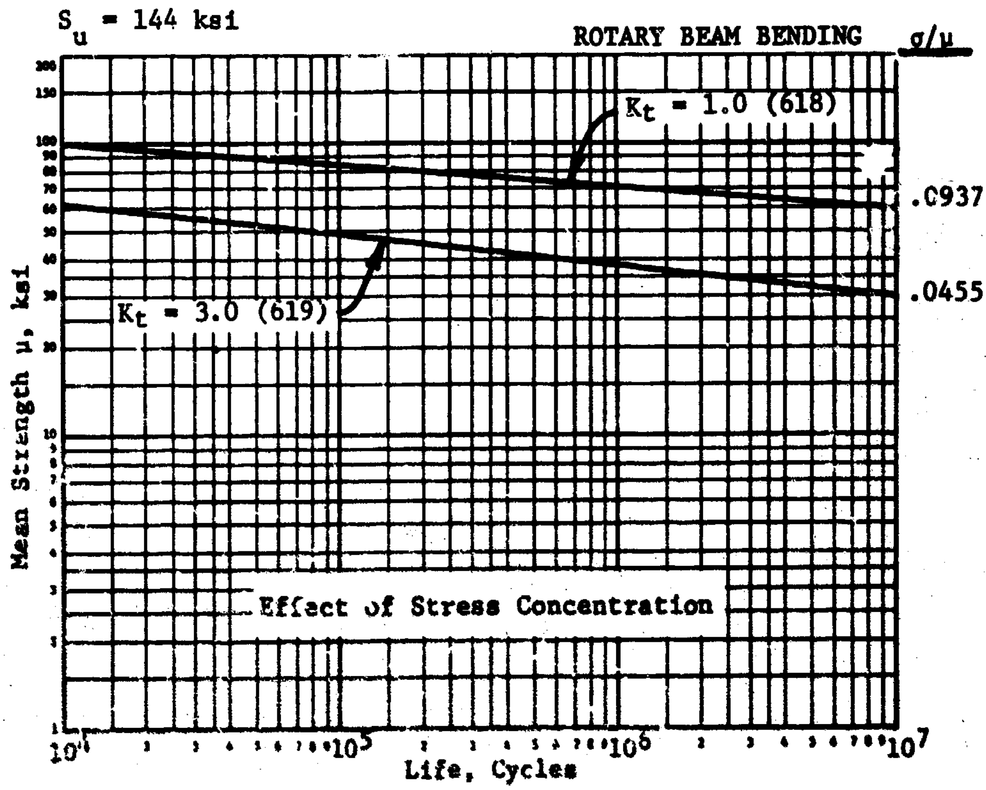
Figure 6.48



(Numbers in parentheses are the code numbers of the tabulated values.)

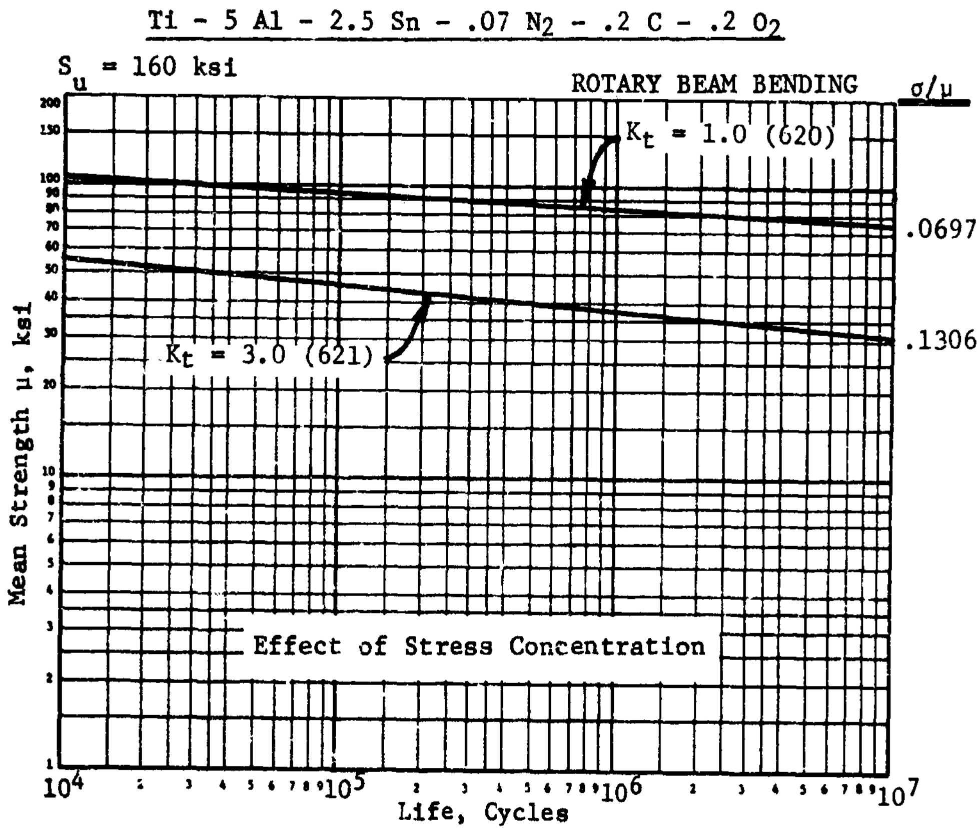
Figure 6.49

Ti - 5 Al - 2.5 Sn - .2 C



(Numbers in parentheses are the code numbers of the tabulated values.)

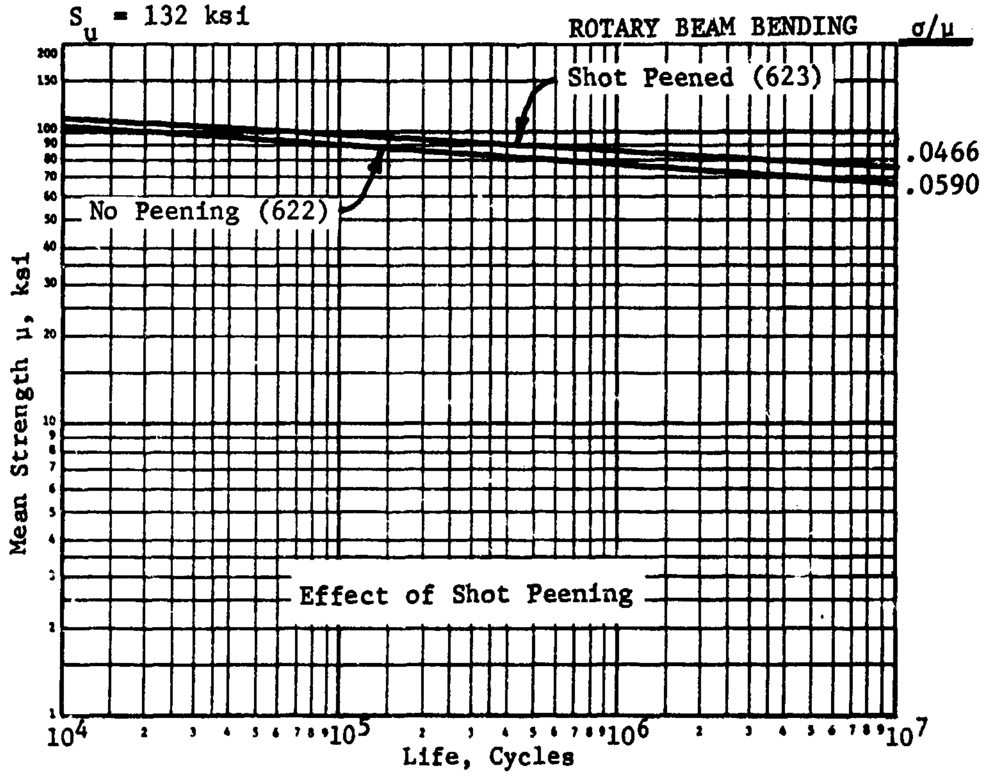
Figure 6.50

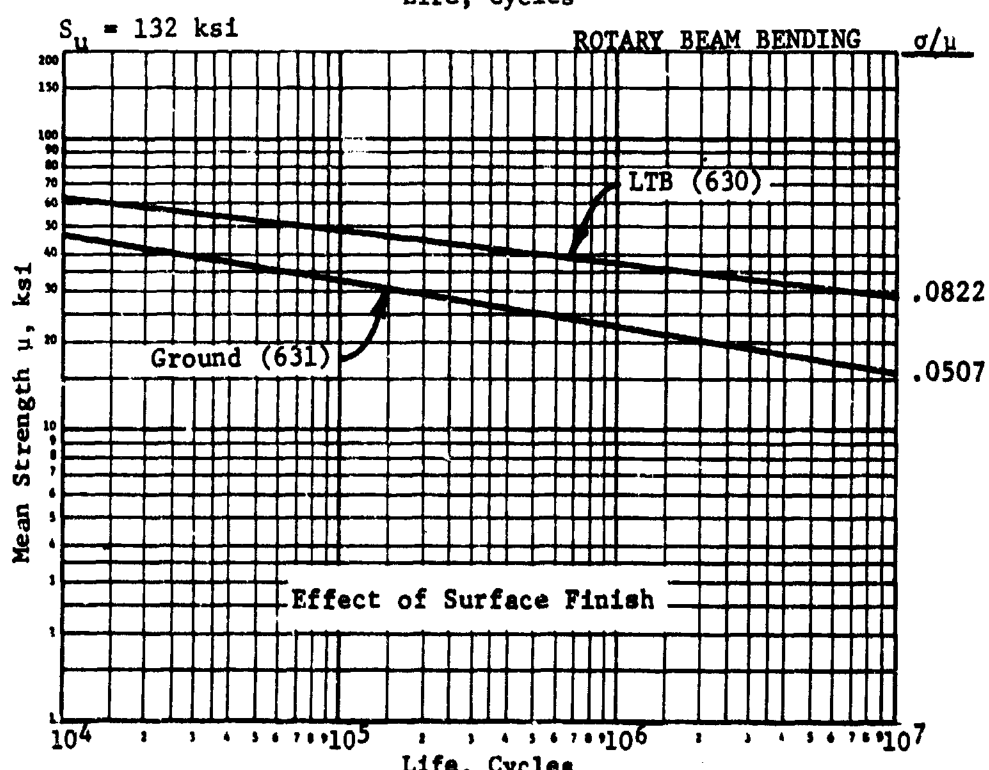


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.51

Ti - 6 Al

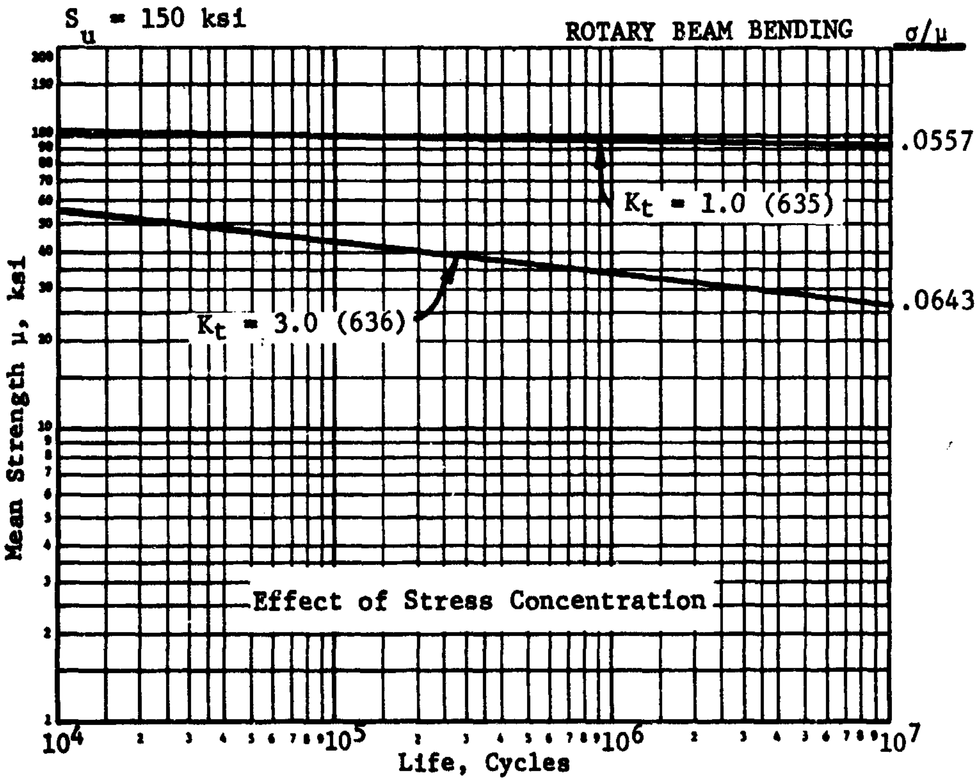


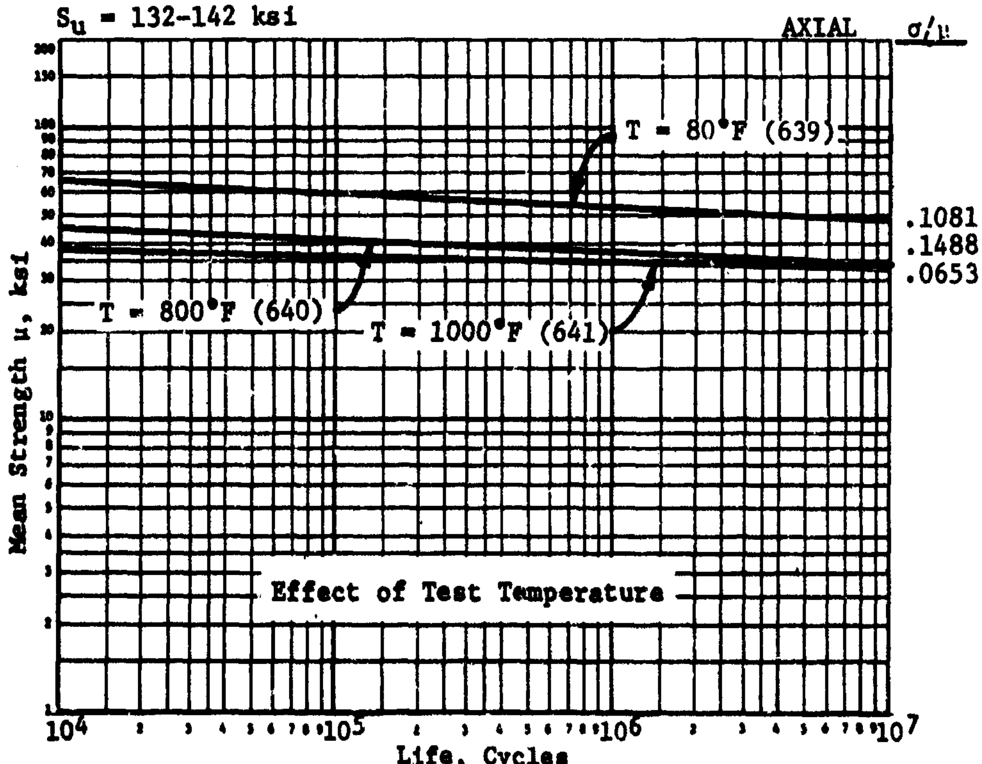


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.52

Ti - 6 Al - 4 V

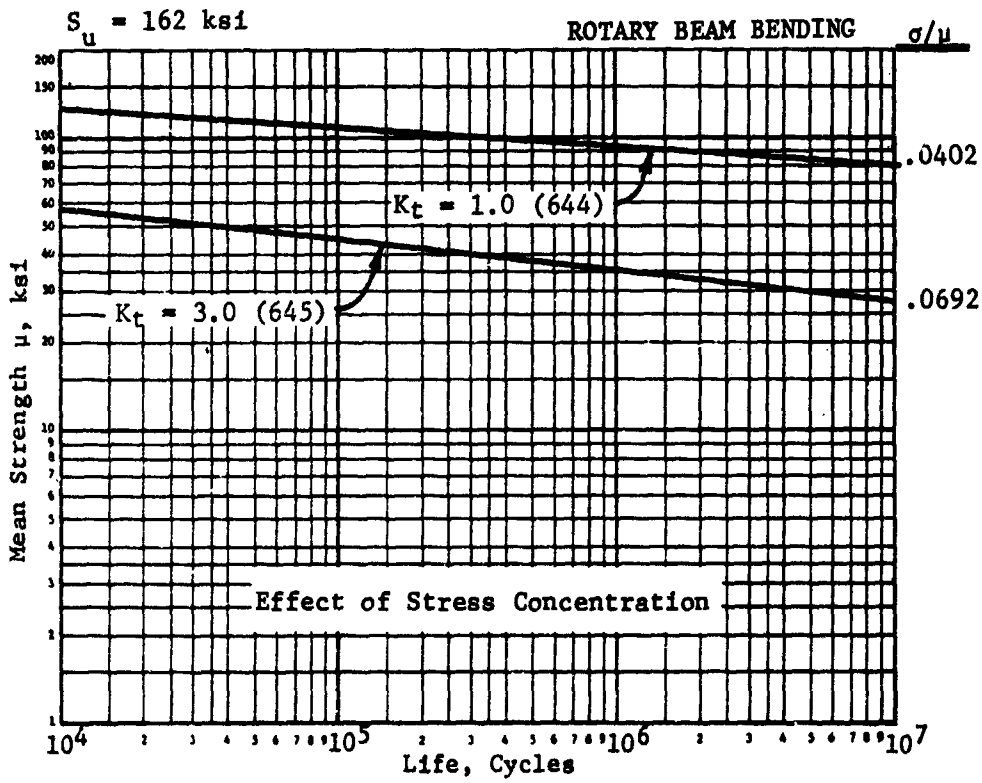




(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.53

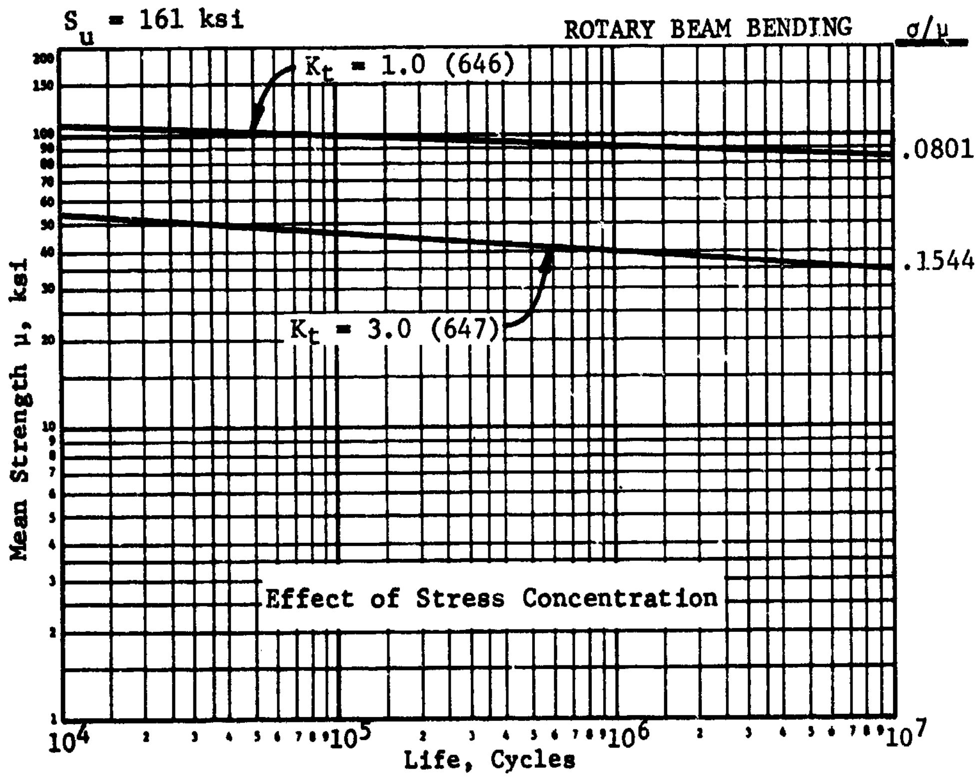
$Ti - 6\ Al - 4\ V - .07\ N_2$



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.54

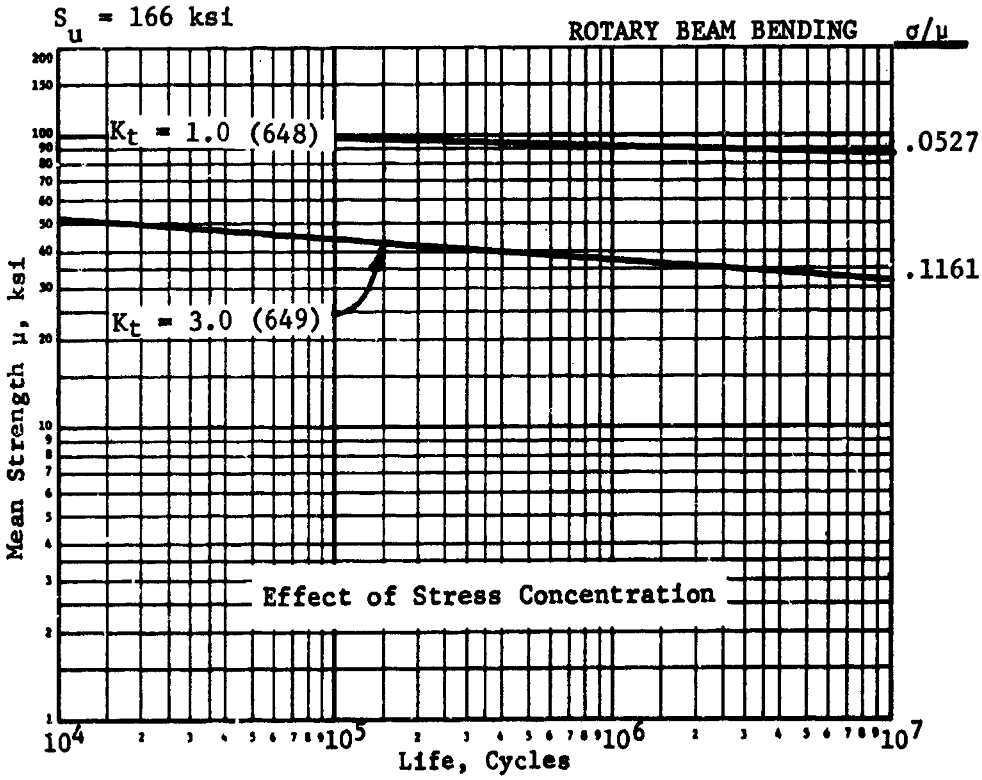
Ti - 6 Al - 4 V - 0.2 O_2



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.55

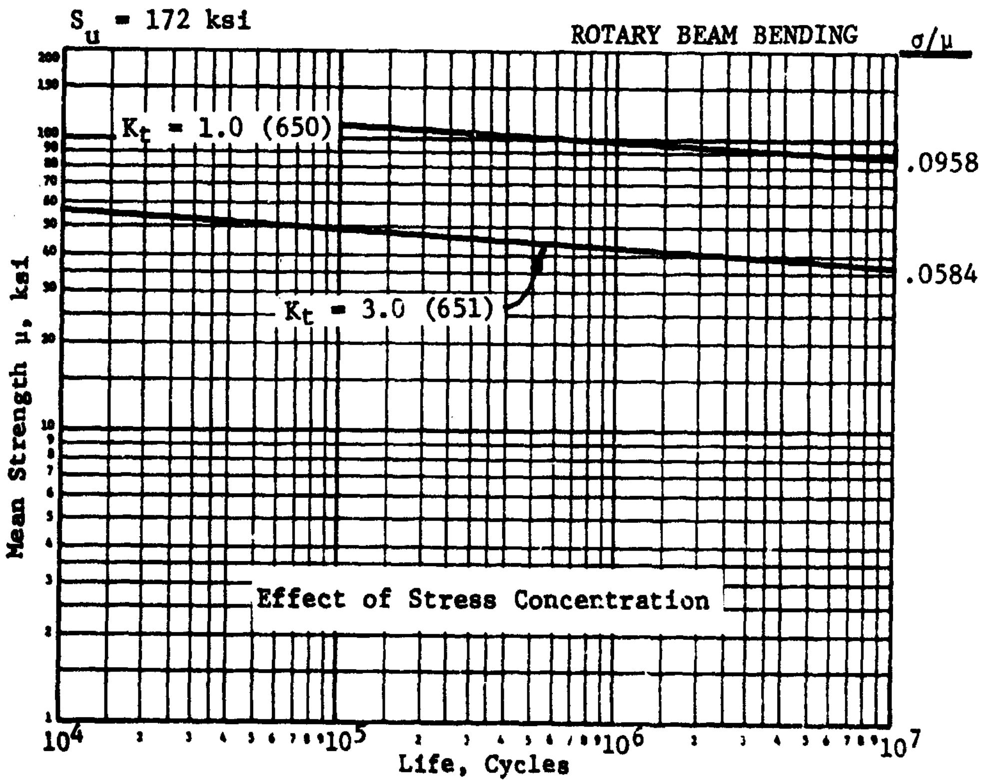
Ti - 6 Al - 4 V - 0.2 C



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.56

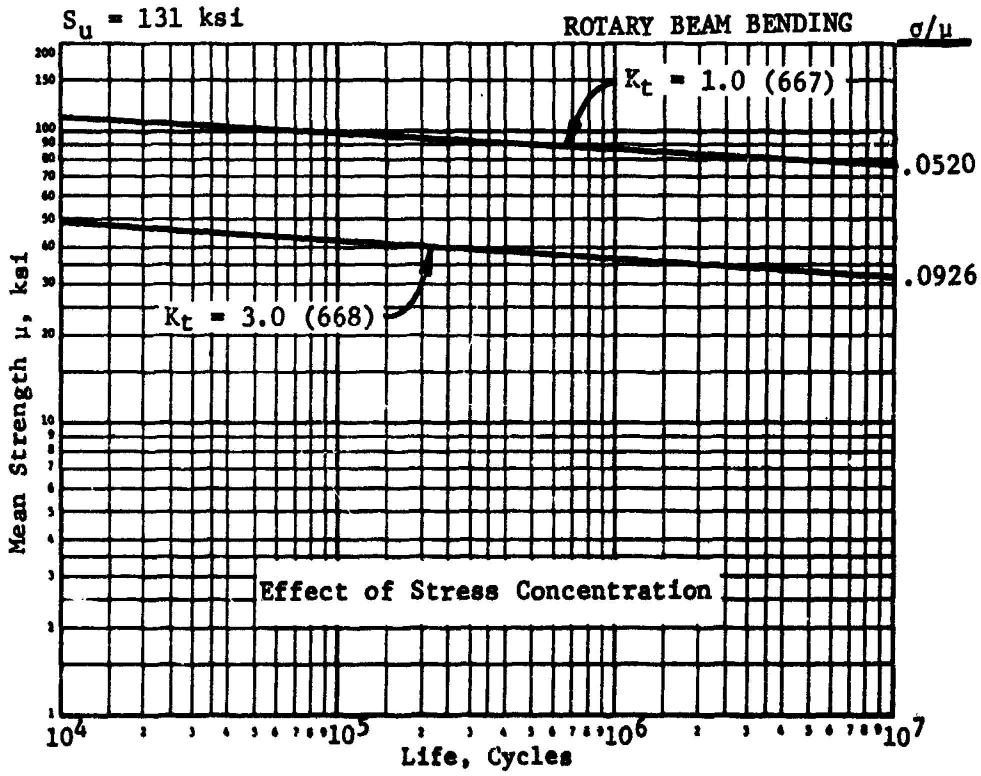
Ti - 6 Al - 4 V - .07 N2 - .2 O2 - .2 C



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.57

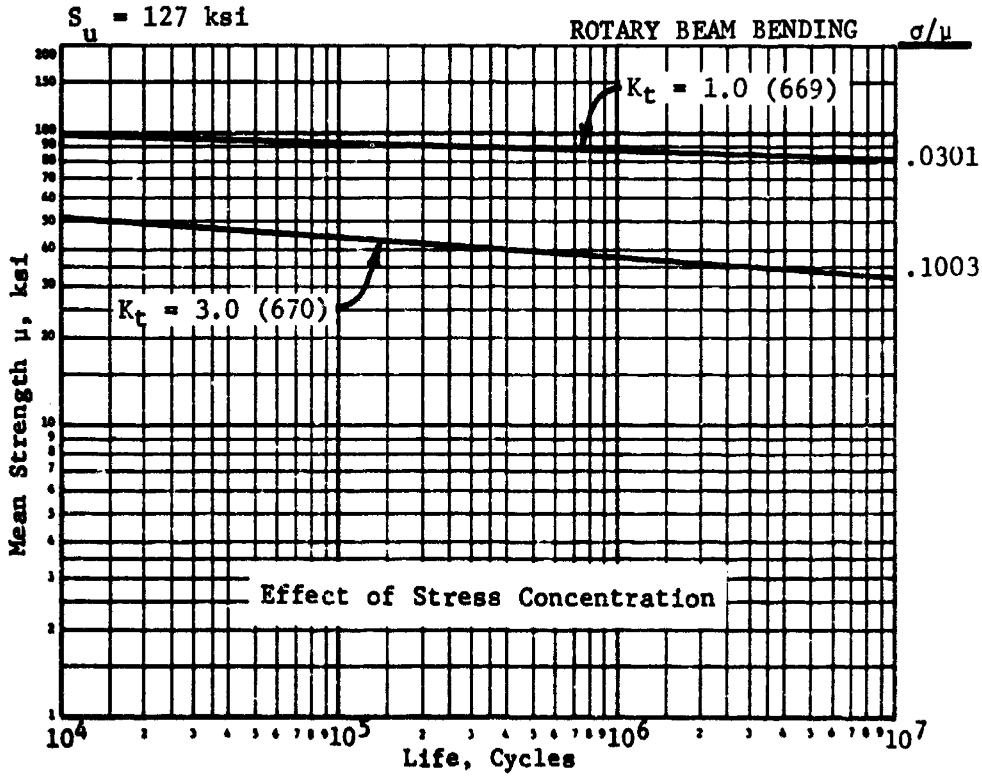
Ti - 3 Mn - 0.2 O_2



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.58

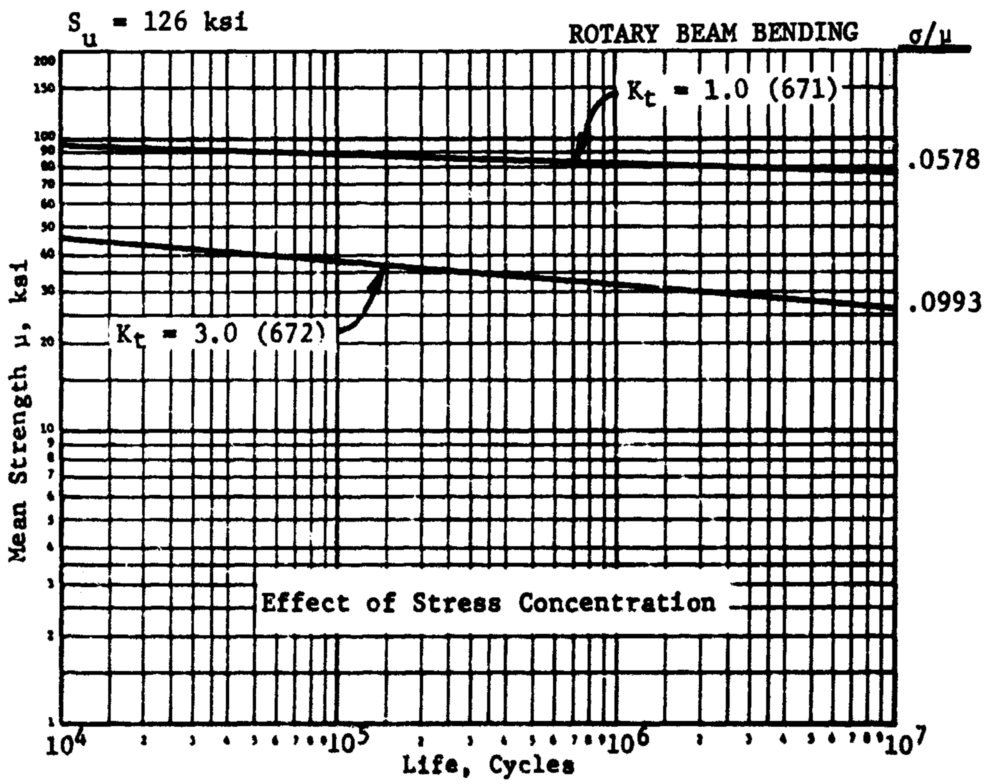
Ti - 3 Mn - .07 N_2



(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.59

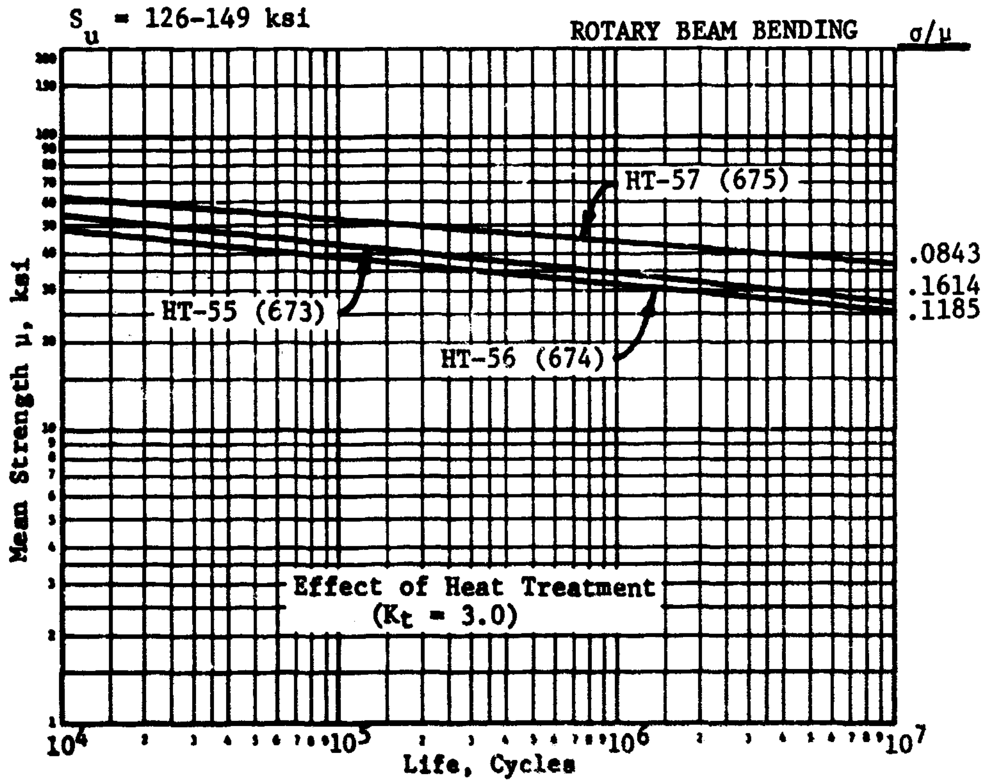
Ti - 3 Mn - .2 C

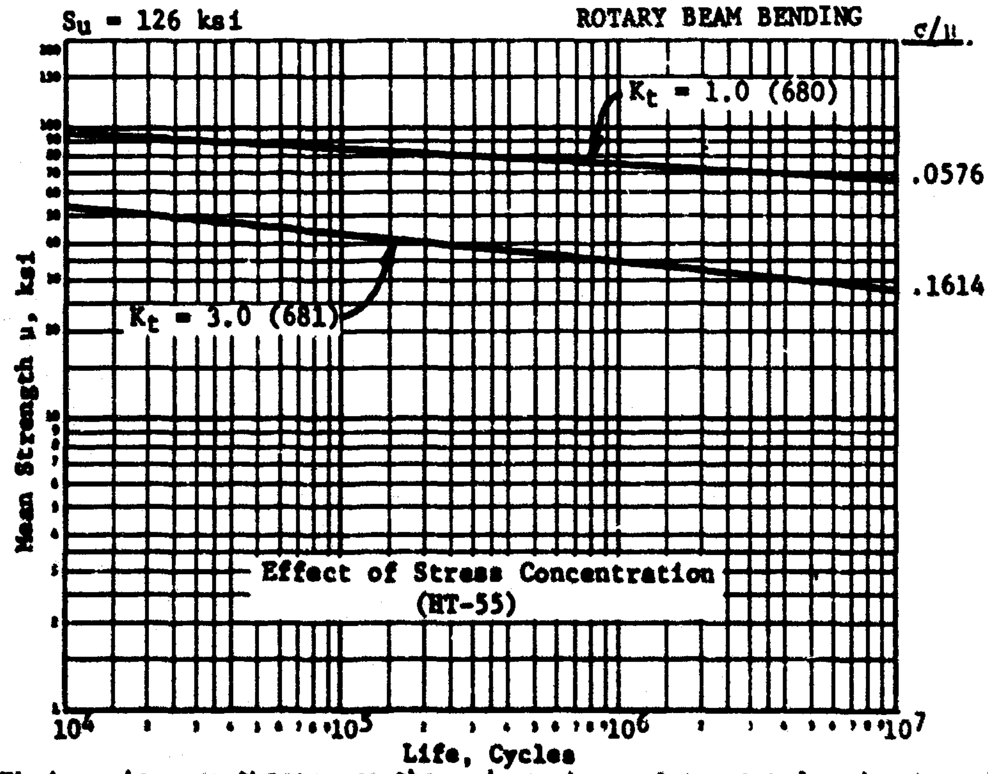


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.60

Ti - 3 Mn COMPLEX

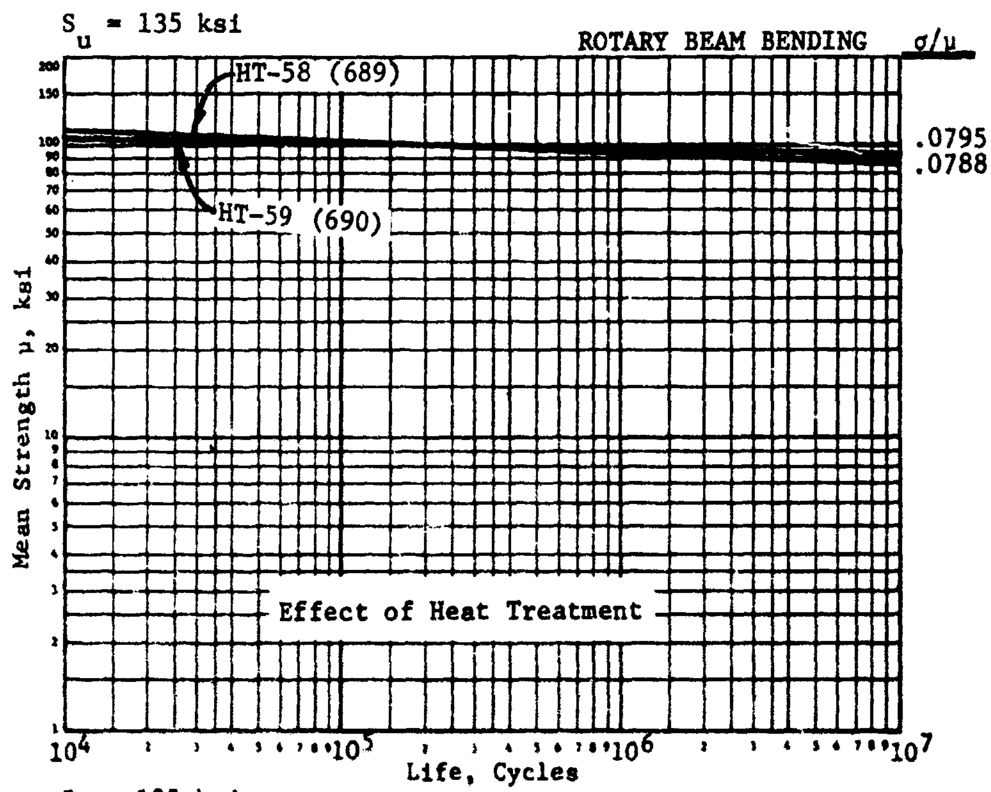


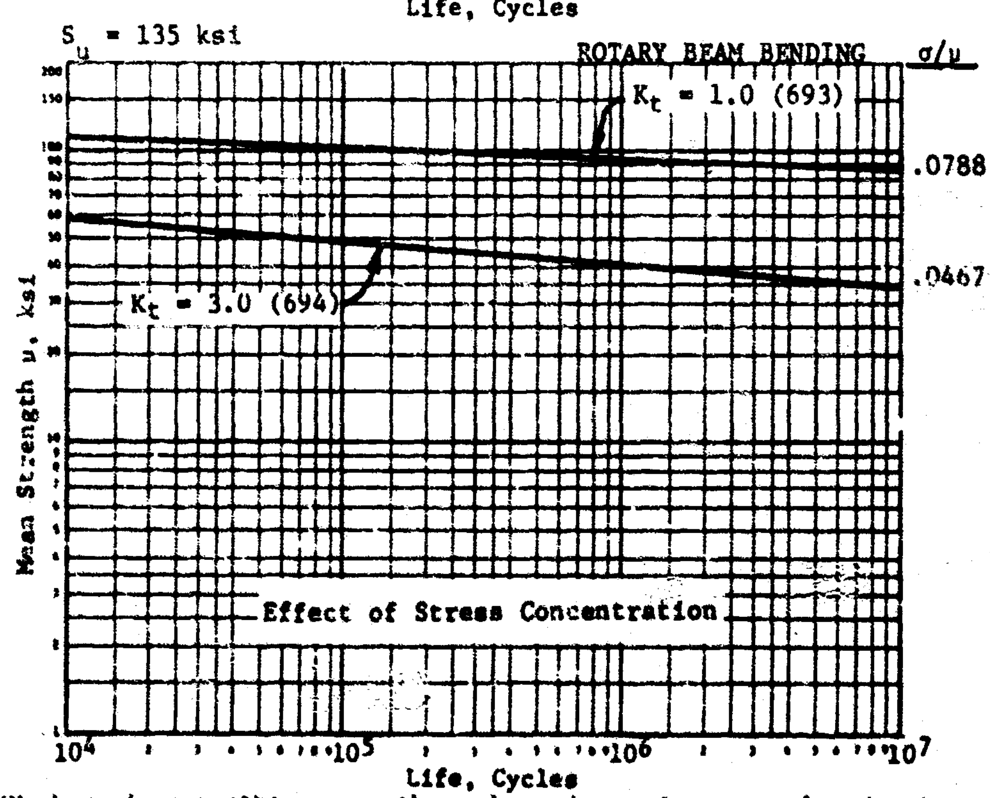


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.61

Ti - 8 Mn

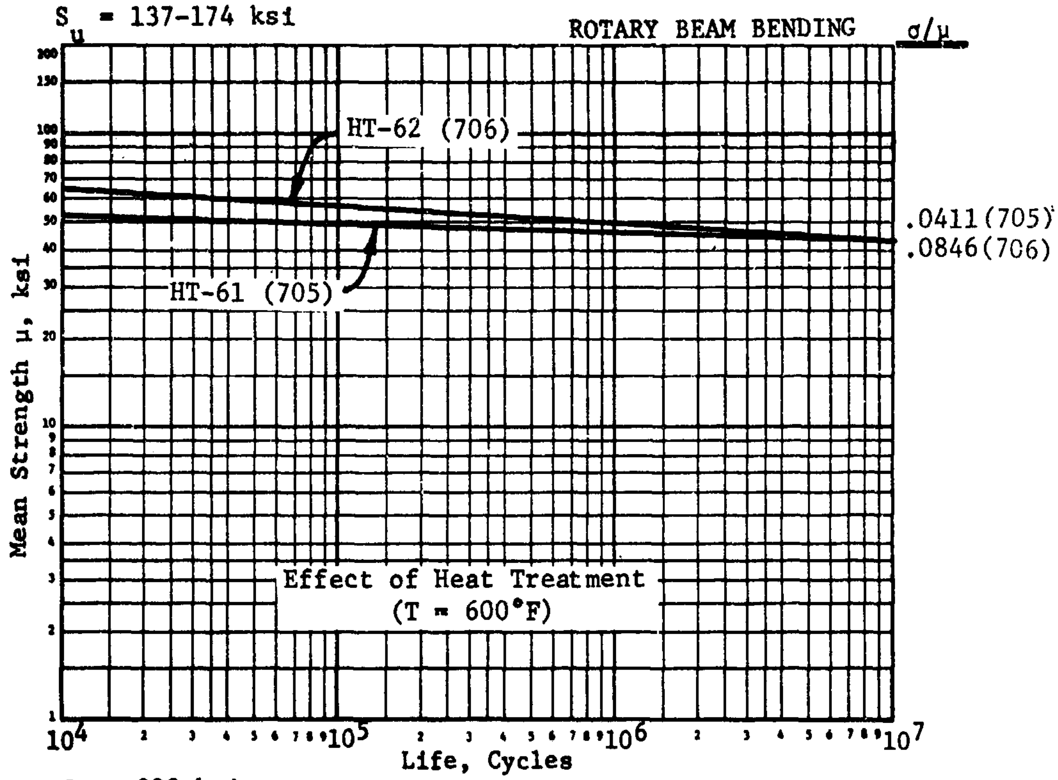


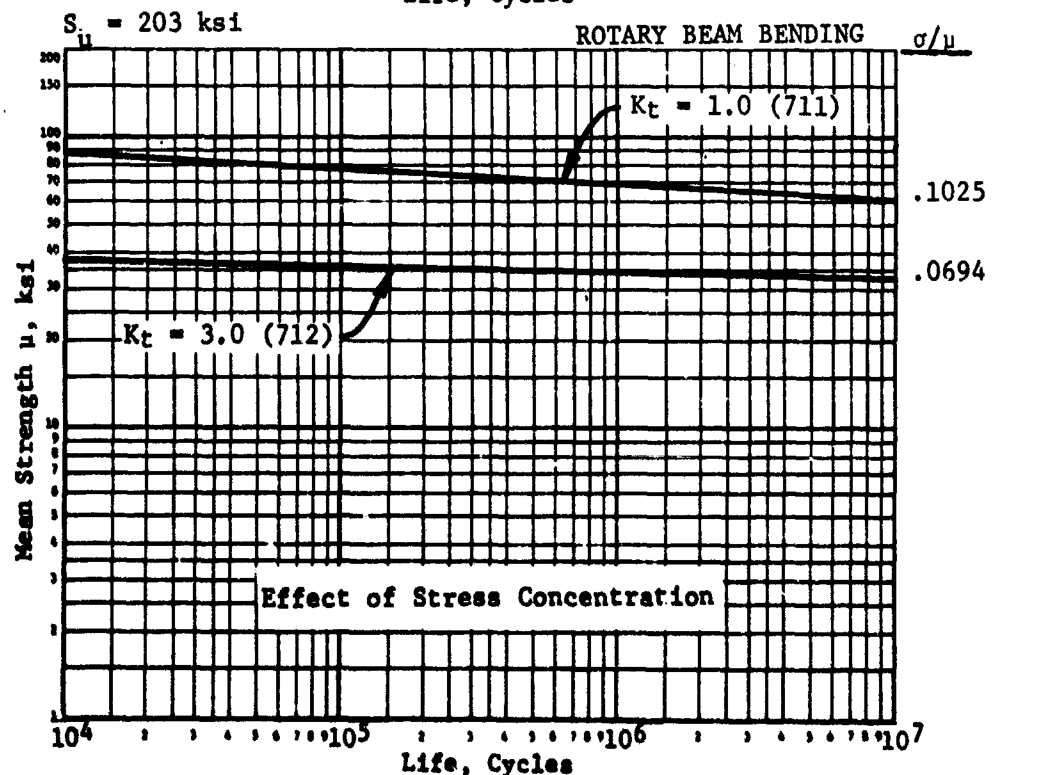


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.62

Ti - 13 V - 11 Cr - 3 Al

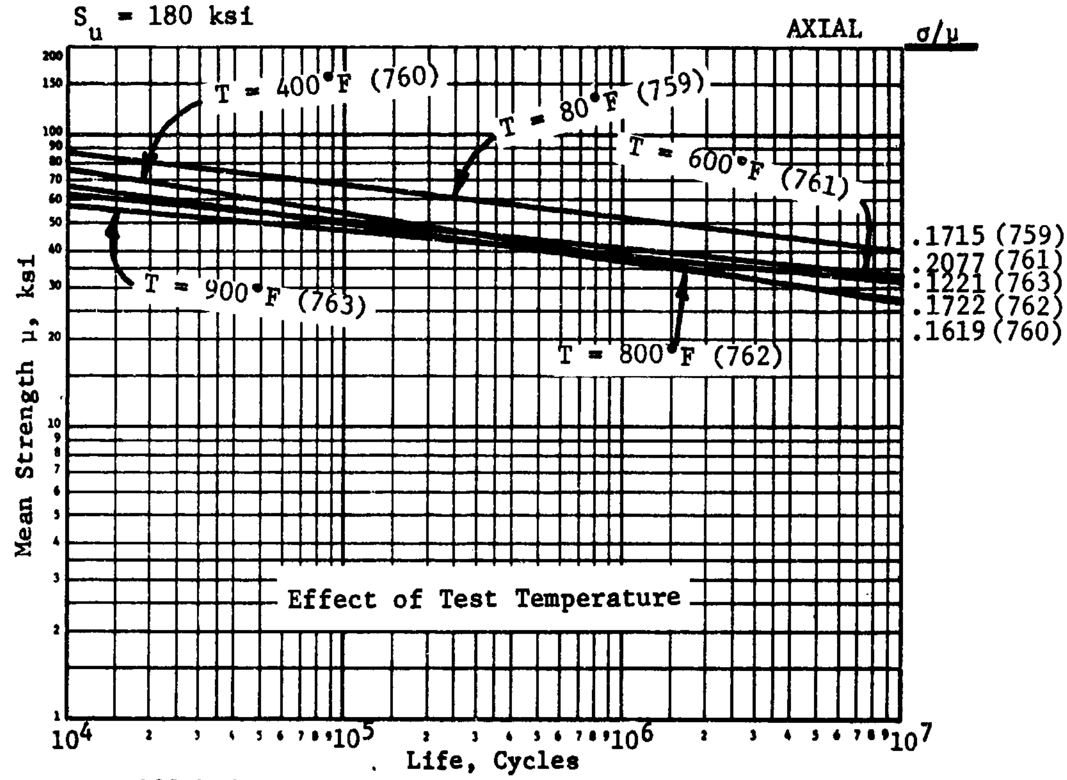


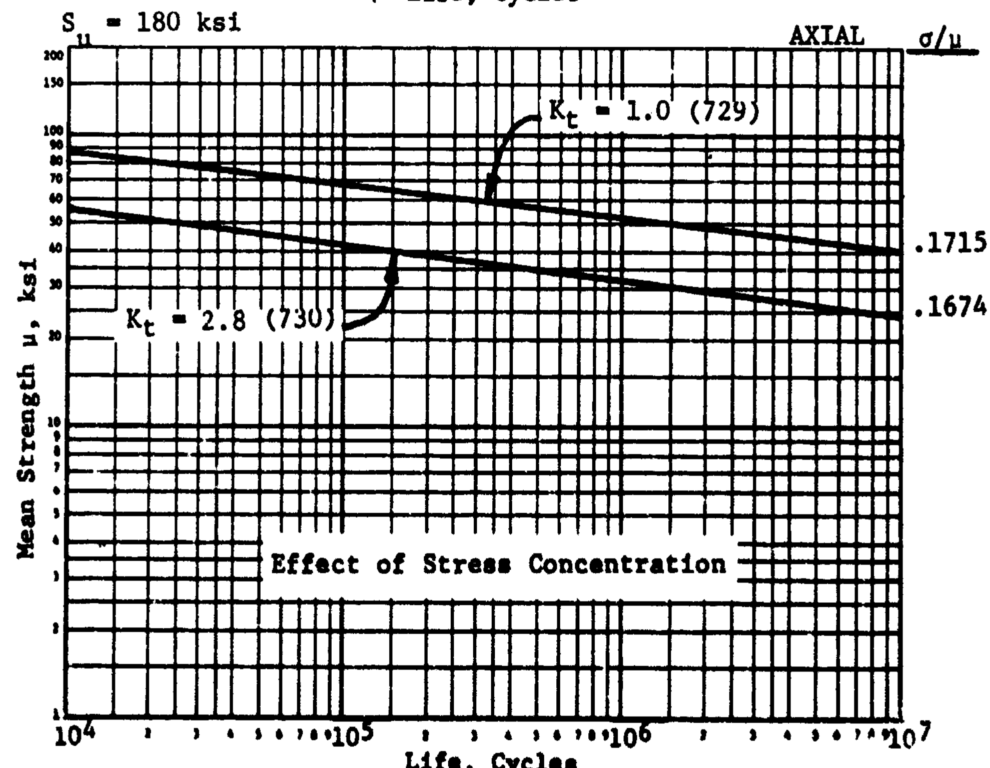


(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.63

Ti - 16 V - 2.5 Sn





(Numbers in parentheses are the code numbers of the tabulated values.)

Figure 6.64

SECTION 7 THE STATISTICAL DISTRIBUTION OF STRESS

7.1. STRESS SPECTRUM VS STRESS DISTRIBUTION

The problem of stress distribution in the Interference Theory appears to be much more involved than the problem of strength distribution. Consider, for example, the problem of an aluminum cylinder head in a reciprocating engine. Because of the variation in hardness, surface finish, etc., the fatigue strength will vary from one cylinder head to another. This will result in a distribution curve in which the strength will be plotted on the abscissa and the number of cylinder heads having a given strength (i.e., frequency of occurrence) on the ordinate.

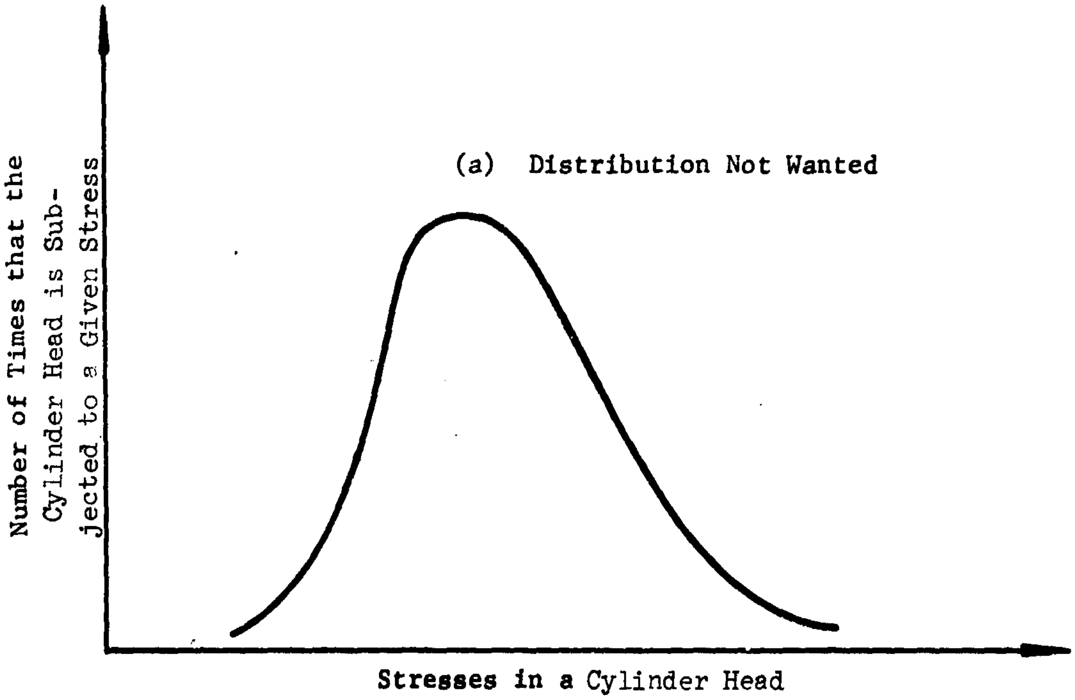
Consider now the stress distribution in the cylinder heads. The stresses in the head result from the gas pressure loading. If the attention is now focussed on a single cylinder head, then the variation in the gas pressure will produce a distribution of stresses in this particular head. The resultant curve will be a plot of the stresses in the head on the abscissa and the number of times that this stress occurs in this particular head on the ordinate [Figure 7.1 (a)].

This, however, is not what is wanted in the application of the Interference Theory, because this distribution of stresses cannot be matched with the distribution of strength. In the strength distribution the ordinate gives the number of cylinder heads having a given strength. Therefore, in the stress distribution the ordinate must be the number of cylinder heads having a given stress (and not the number of times a given stress occurs in a single head). This can be obtained by considering the fact that different engines will be subjected in service to different operating conditions, and therefore, the distribution of gas pressure loading will vary from engine to engine. As pointed out in Section 7.2, a spectrum of stresses must be converted to an equivalent stress for the purpose of Interference Theory. Therefore, if a spectrum of loading due to different service conditions varies from engine to engine, in a population of cylinder heads, the equivalent stress will vary from head to head. Thus the statistical stress distribution desired for the Interference Theory may be obtained [Figure 7.1 (b)]. In this distribution the equivalent stress will be plotted on the abscissa and the number of cylinder heads (frequency of occurrence) having that stress on the ordinate. This distribution then can be compared with the strength distribution to obtain the probability of Interference.

7.2 CONVERSION OF A STRESS SPECTRUM TO AN EQUIVALENT STRESS (S_{equ})

By definition, the equivalent stress is a completely reversed stress of constant amplitude which, when imposed on a part, should cause failure at the same life as if the stress spectrum was imposed instead. Thus, the damage accumulated at any given life, due to this equivalent stress, will be the same as if due to the spectrum of stresses.

The first step towards converting the spectrum to a single stress (S_{equ}) is to convert the operating stresses, which may have some mean stress associated with them, to zero mean stress, that is, to a completely reversed stress.



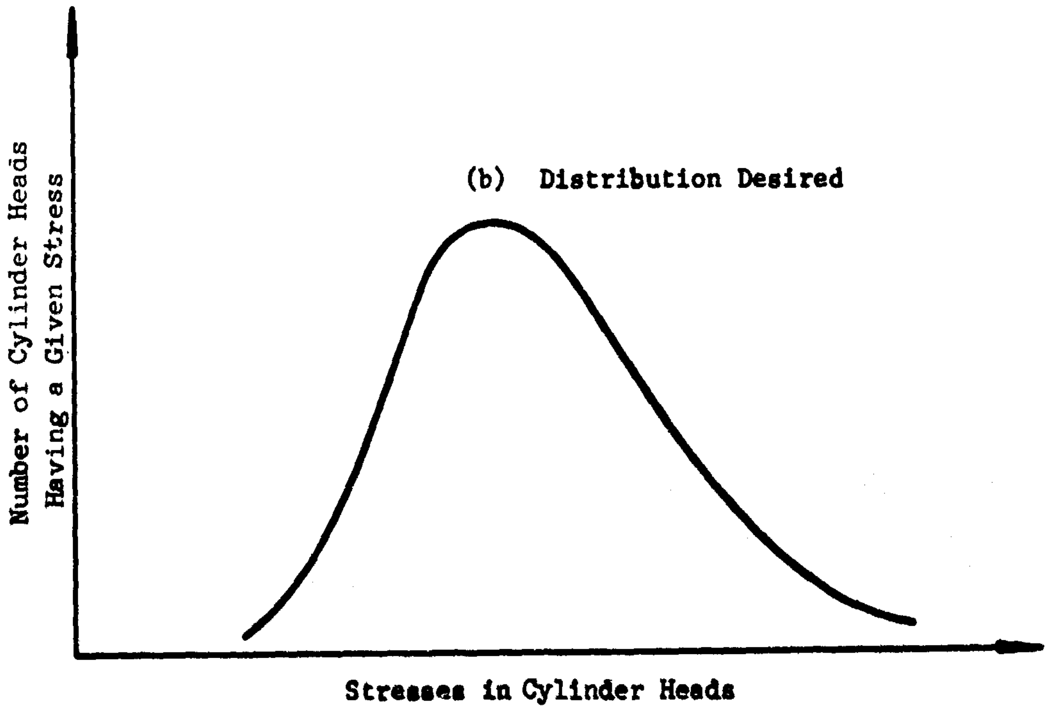


Figure 7.1 Stress Distribution for the Interference Theory

(Figure 7.2). This can be done by means of the modified Goodman diagram. Draw the Goodman diagram as shown in Figure 7.3. From the spectrum of operating stresses plot each stress cycle on this diagram as shown, for example, line AB. Connect CA and CB and extend to the vertical line where the mean stress is equal to zero. Hence, XY is the zero mean stress equivalent to AB. After reducing all such stress cycles to zero mean stress, the stress spectrum will have all the stress cycles completely reversed. The magnitude of XY will be different for different stress cycles. Therefore, the original operating stress spectrum [Figure 7.2 (a)], with various mean stress levels, is thus reduced to a stress spectrum with zero mean stress, that is, to a completely reversed stress (Figure 7.4).

This spectrum can then be reduced to a single equivalent stress of constant amplitude by means of Miner's or Corten-Dolan's Rule.

7.2.1 Miner's Rule

Miner's Rule[10] assumes that the total life of a component can be estimated by simply adding the fraction of life consumed by each over-stress cycle. Overstress can be defined as the stress above the endurance limit of the material which, if applied, will damage the part. This rule is expressed as:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \dots \frac{n_k}{N_k} = 1$$

or

$$\sum_{i=1}^{i=k} \frac{n_i}{N_i} = 1 \tag{7.1}$$

where $n_1, n_2, n_3 \dots n_k$ represent the number of cycles at specific overstress levels; $N_1, N_2, N_3 \dots N_k$ the life cycles to failure at these levels as read from the S-N curve, and $\Sigma \frac{n_i}{N_i}$ is the fraction of the total life consumed by Σn_i cycles.

The equivalent life (the total life) of a part (N_{equ}) under a spectrum of stresses may be found by proportion:

$$\frac{N_{equ}}{1} = \frac{\sum\limits_{i=1}^{i=k} n_i}{\sum\limits_{i=1}^{i=k} \frac{n_i}{N_i}}$$

Suppose, for example, there are three stress levels, 90, 70, and 50 ksi, in a given spectrum. With reference to the curve in Figure 7.5, $1/(6 \times 10^4)$ is the fraction of life consumed by each 90 ksi stress cycle, $1/(5 \times 10^5)$ by each 70 ksi cycle, $1/(8 \times 10^5)$ by each 55 ksi cycle, etc. Using Equation (7.2):

$$N_{equ} = \frac{1 + 1 + 1}{\frac{1}{6 \times 10^4} + \frac{1}{5 \times 10^5} + \frac{1}{8 \times 10^5}} = 1.5 \times 10^5 \text{ cycles}$$

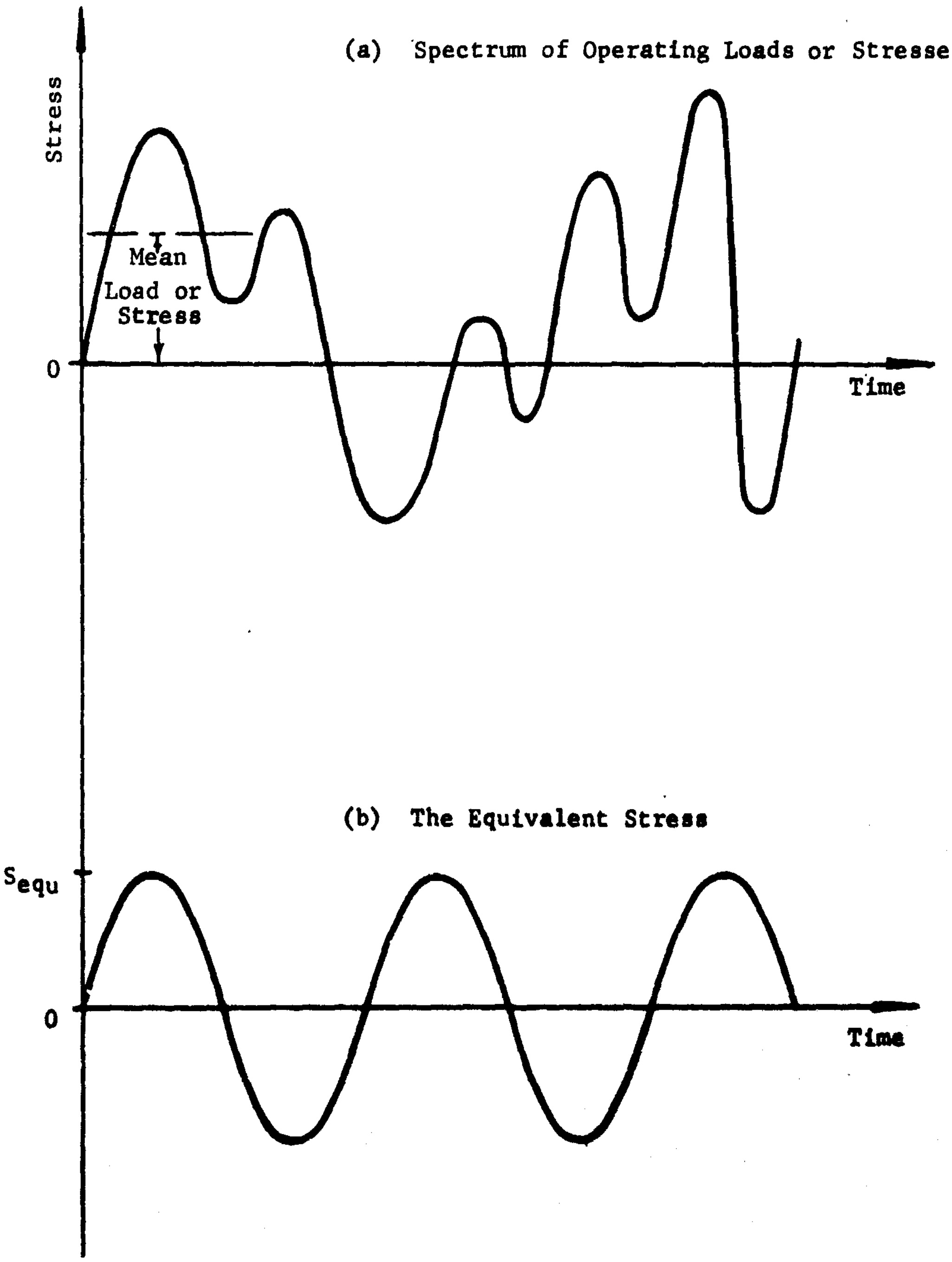


Figure 7.2 Conversion of a Stress Spectrum to An Equivalent Stress

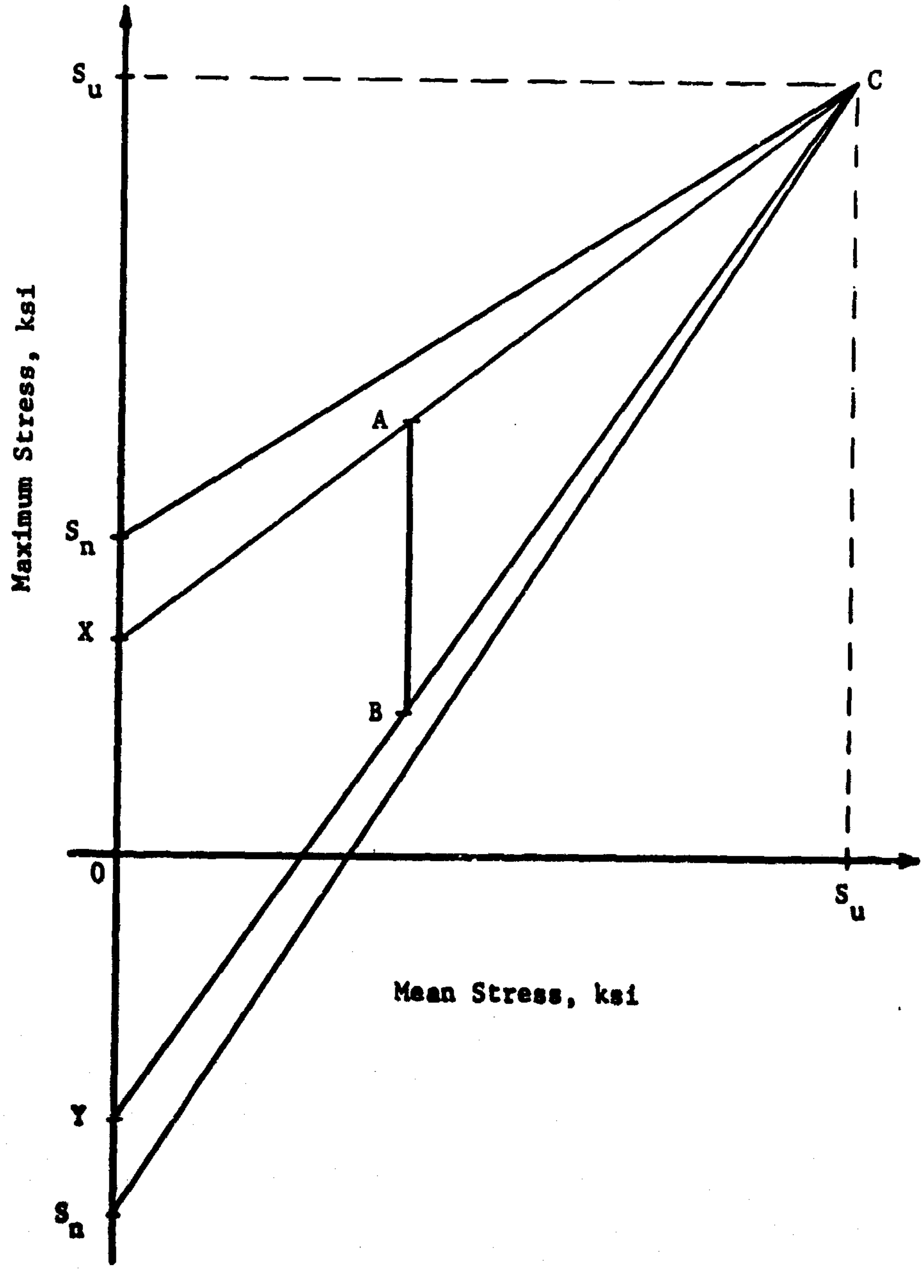


Figure 7.3 A Modified Goodman Diagram

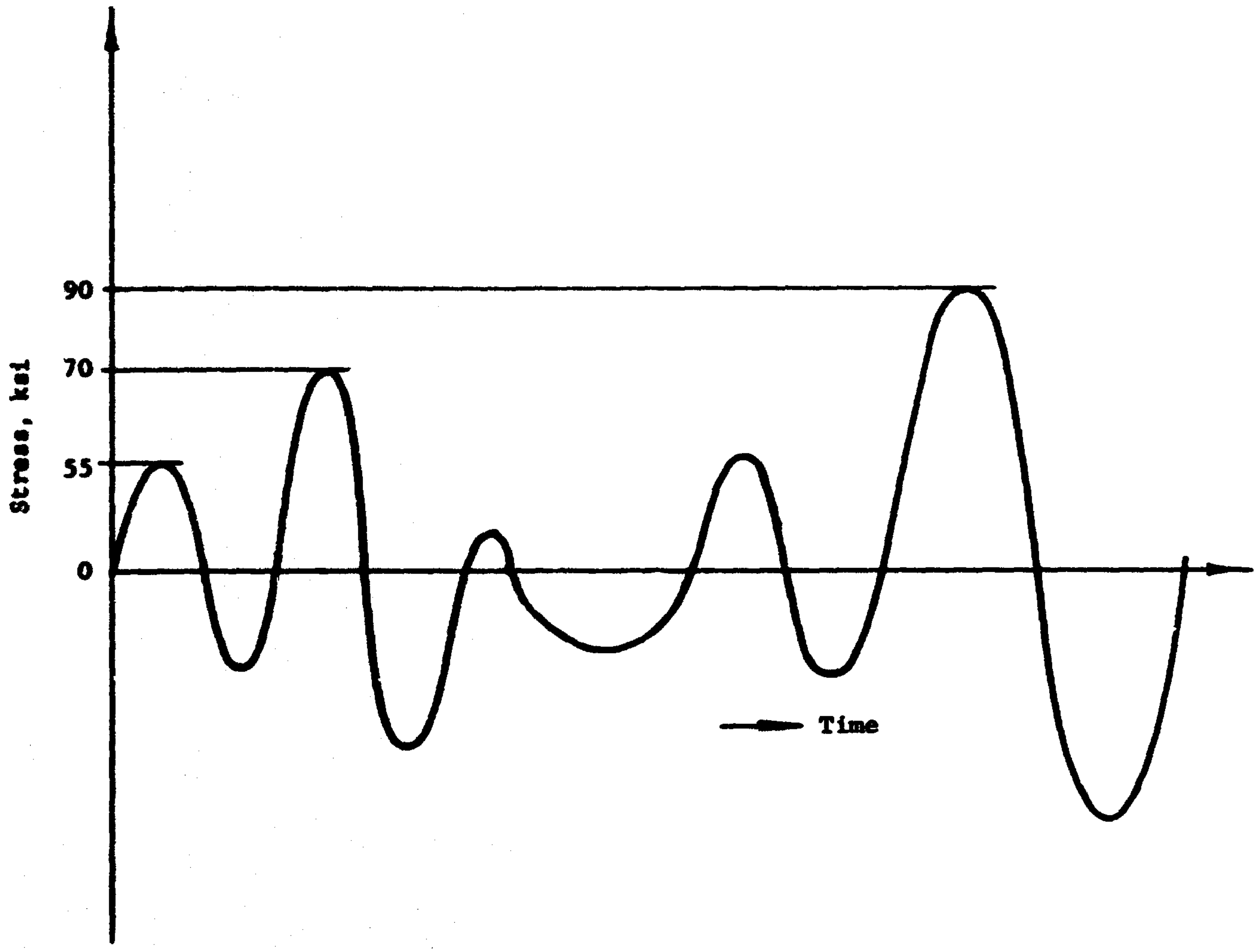


Figure 7.4 The Completely Reversed Stress Reduced from the Stress Spectrum by Means of a Modified Goodman Diagram

Thus, the life of the part under the above spectrum of stresses will be equivalent to a life of 1.5×10^5 cycles. The completely reversed stress equivalent to this life is (from Figure 7.5) 75 ksi. Hence, the damage that the part accumulates due to the above spectrum of varying stress amplitude will be the same as if stress cycles of constant amplitude equal to S_{equ} (in this case 75 ksi) were imposed for N_{equ} (1.5×10^5 cycles). Thus, the spectrum of stresses can be replaced by a single stress.

Miner's Rule, as stated in Equation (7.1), gives one (1.0) as the criterion for failure. Miner's original tests showed that the value for the summation in Equation 7.1 actually varied between 0.61 and 1.45. His more recent data[11] gives a range of 0.7 to 2.2. Other sources[12] quote a range as high as 0.18 to 23.0. In view of all this scatter, it is generally agreed that the value of one (1.0), originally proposed by Miner, is probably the best overall estimate that can be made at this time.

7.2.2 Corten-Dolan's Rule

The application of this rule in converting the stress spectrum to a single equivalent stress (S_{equ}) is identical to that of Miner's rule, except that the S-N curve used to obtain the life values $N_1, N_2, \ldots N_k$ is modified. This modification is done, as shown in Figure 7.6, by changing the slope of the S-N curve. A line is drawn with an inverse slope, d, passing through the point N_1 on the S-N curve, having the maximum stress amplitude (in this case, S_1) occurring in the stress spectrum. This new line is known as the Corten-Dolan line.

From available data[13,14] it appears that for specimens having no stress concentration ($K_f = 1$), the value of $d/d' = 0.8$ is a reasonable estimate. A recent study by Harris and Lipson[15] indicates that when stress concentrations are present the following relationship can be used

$$d/d' = (0.73 + 0.07\,K_f) \tag{7.3}$$

This can be graphically expressed as in Figure 7.7. It will be noted that if $K_f = 3.5$, $d/d' \cong 1$, and this becomes equivalent to the criterion obtained from Miner's Rule.

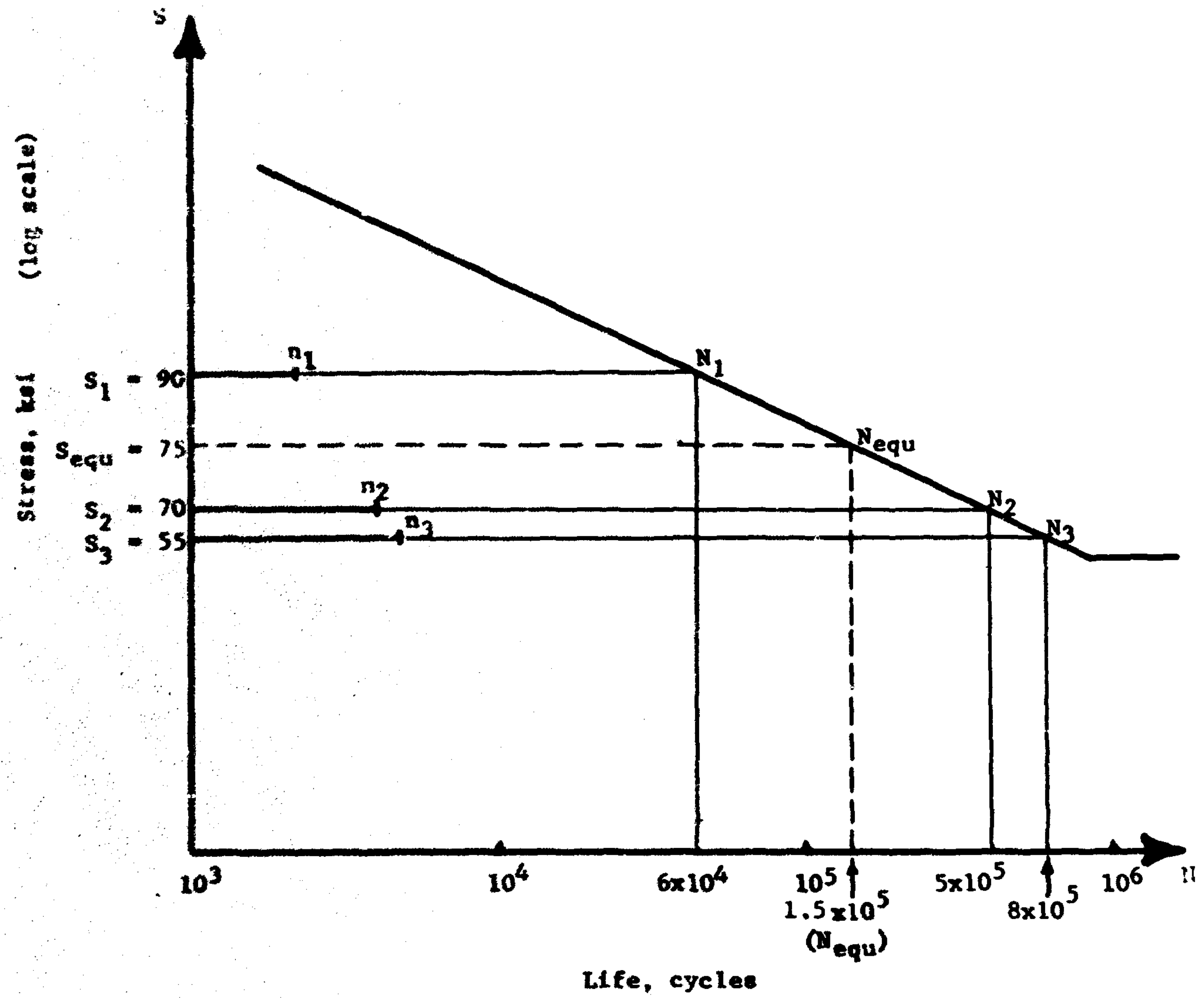


Figure 7.5 Miner's Rule

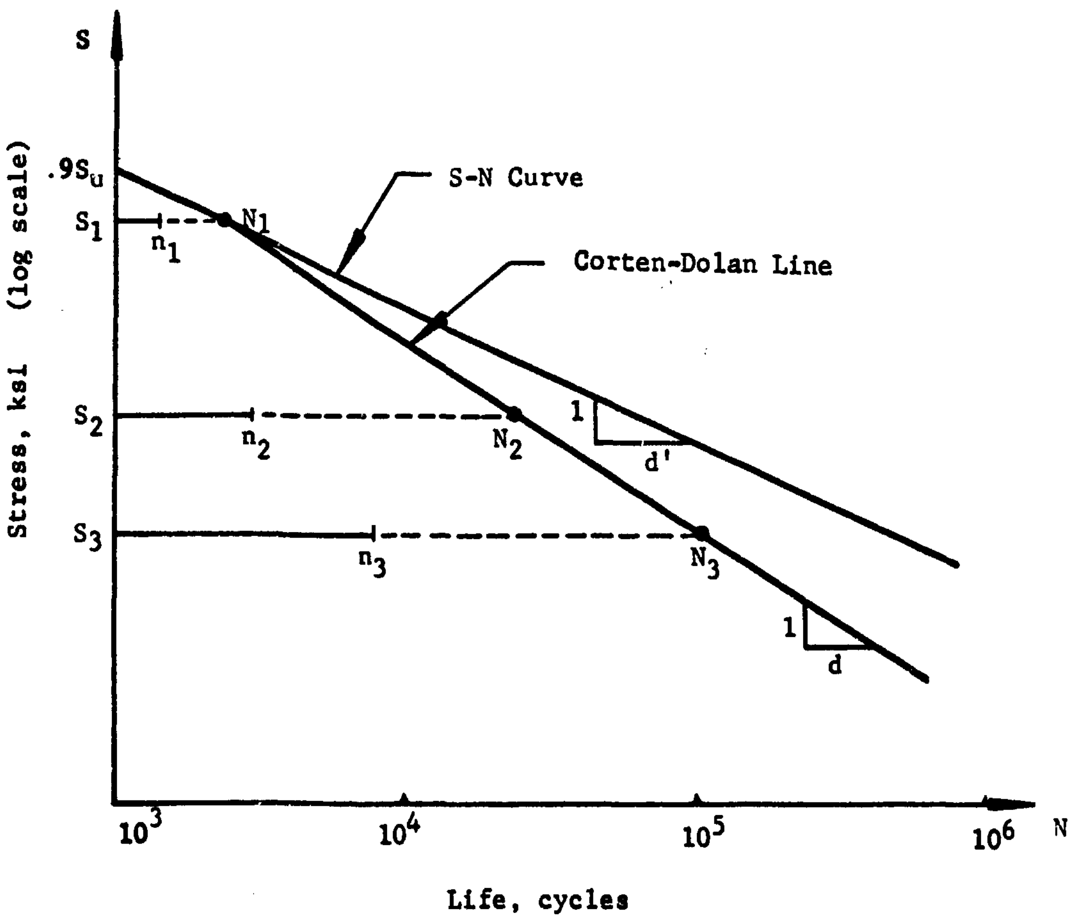


Figure 7.6 The Corten-Dolan Line vs. the S-N Curve

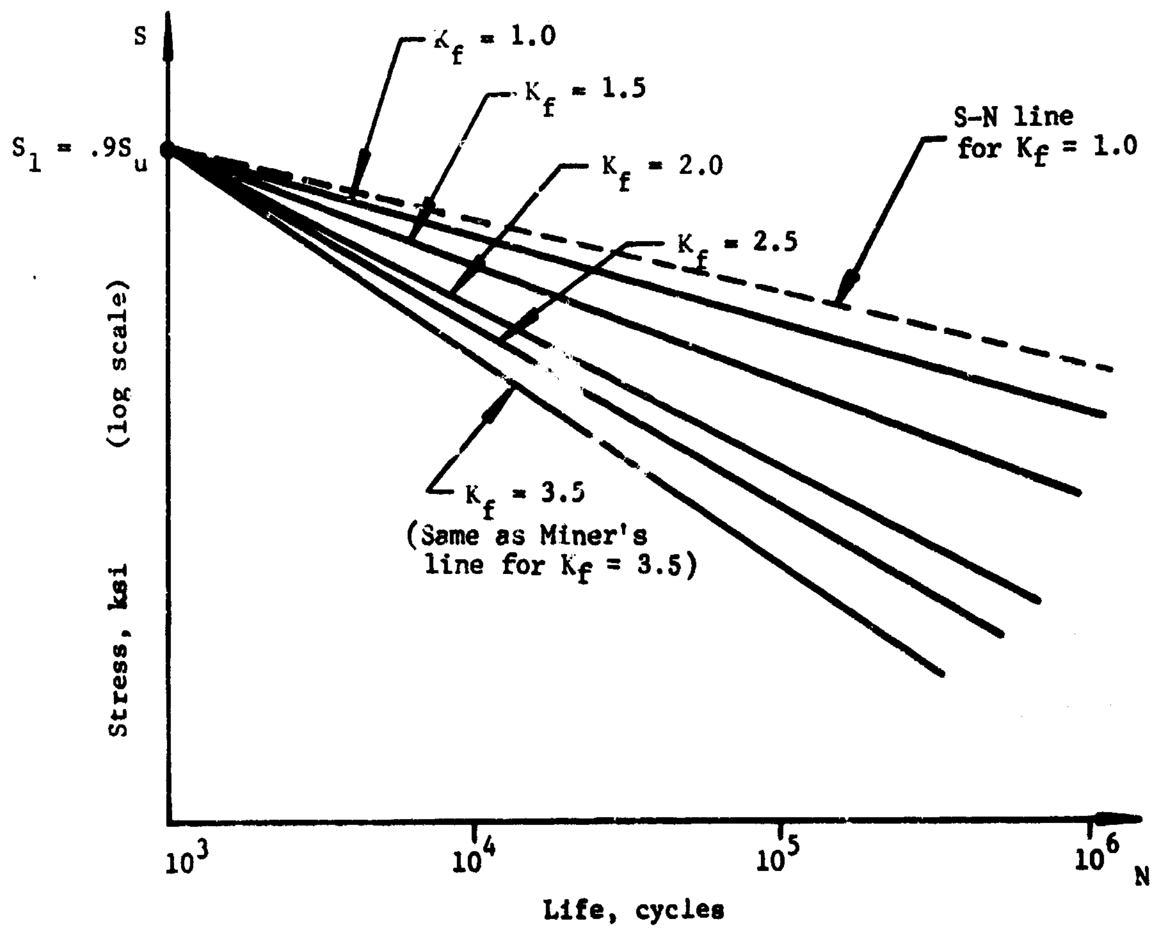


Figure 7.7 Corten-Dolan's Lines for Various Stress Concentration Factors, According to Harris and Lipson(15)

SECTION 8 THE INTERFERENCE OF A STRESS DISTRIBUTION WITH A STRENGTH DISTRIBUTION

After the strength distribution and the stress distribution are determined (Sections 6 and 7 respectively), the two are compared and the percent interference is determined as discussed in Section 2, Section 5, and in detail in Section 9. For a given strength distribution the percent interference will depend on the distribution of the equivalent stress S_{equ}. A search through literature and other sources produced a considerable amount of data leading to the distribution of strength but very little information on the distribution of stress.

In some engineering applications there is very little scatter in stresses. This leads to a stress distribution with a standard deviation equal to zero. This distribution can be represented by a straight line, as in Figure 8.1, and the interference can be determined as shown.

For a given S_{equ}, interference may increase or decrease if the life to which the components are designed is changed. This is shown in Figure 8.2, and in terms of S-N diagram in Figure 8.3. The shape of the distribution curve in Figure 8.2 is different from those in Figure 8.3 because the former are plotted on a linear scale and the latter on a log-log scale.

In those engineering applications where the scatter in stresses is appreciable, the above approach will obviously not apply. On the basis of past experience, in the present investigation the stress distribution (S_{equ}) was assumed to be normal and the range of standard deviations to be not less than $.01\mu$ and not more than $.10\mu$ where μ is equal to S_{equ}. The resulting interference is represented qualitatively in Figure 8.4.

Examples of design problems employing this method are given in Section 9.

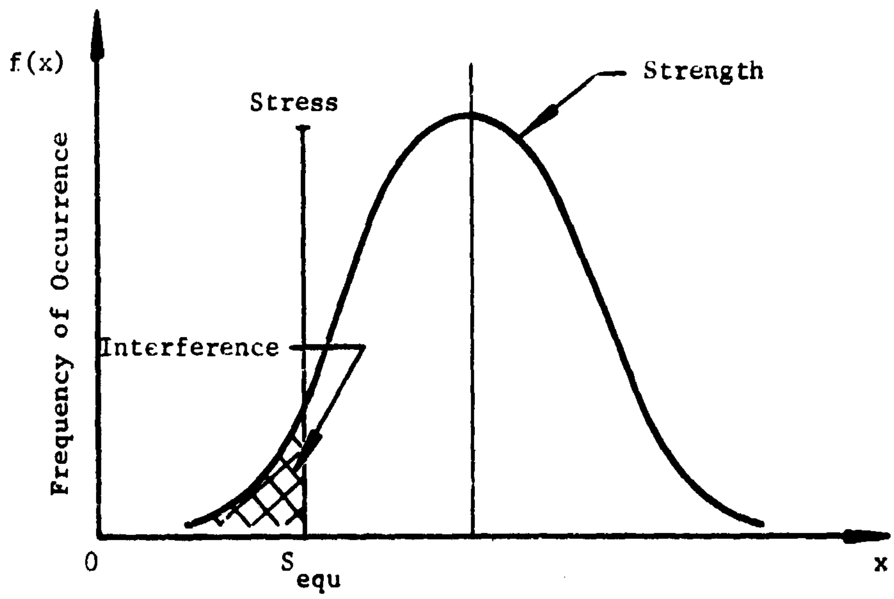


Figure 8.1 Interference with Standard Deviation of Stress equal to Zero

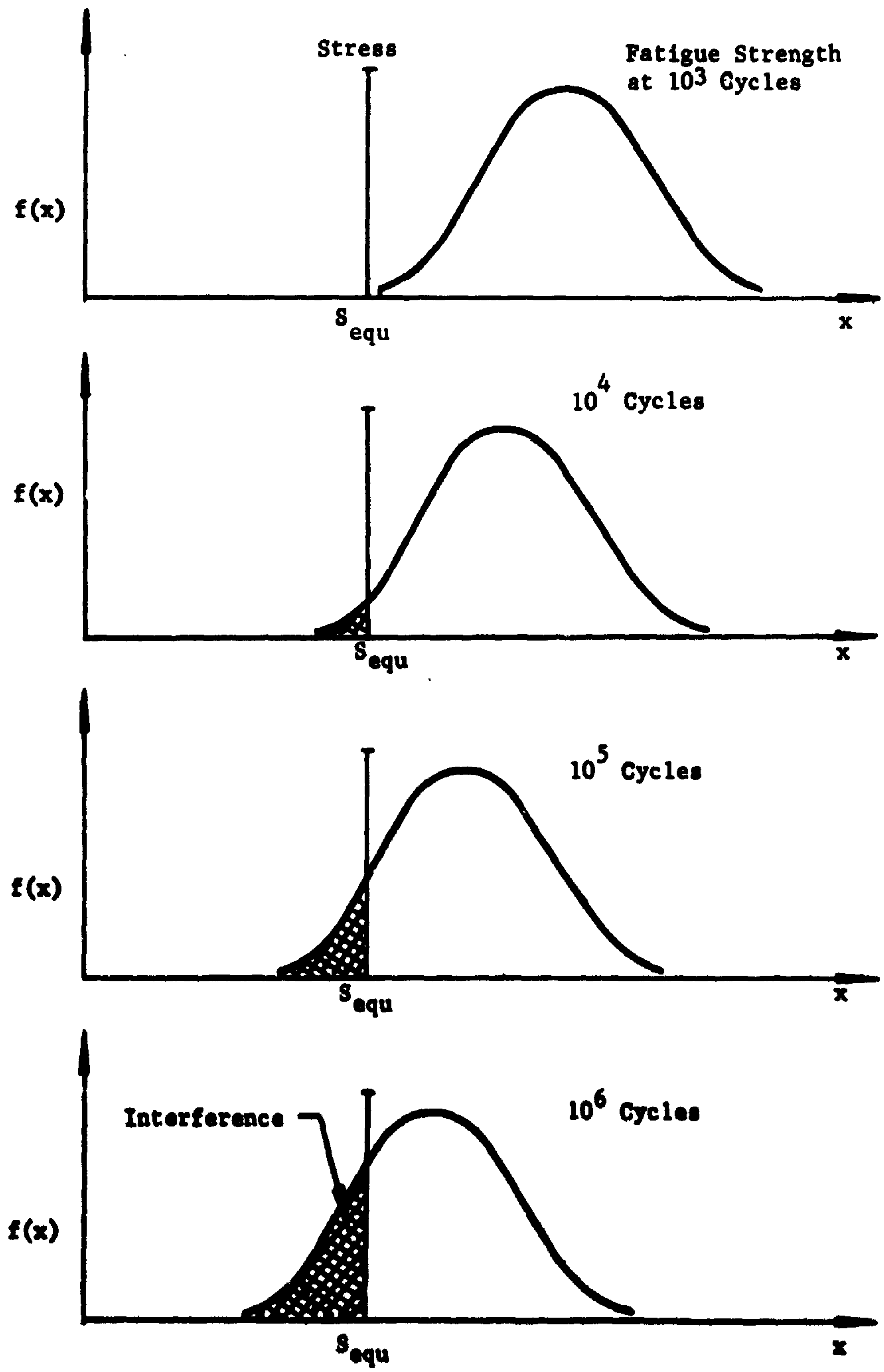


Figure 8.2 Interference of S_{equ} with Strength Distribution at Different Lives

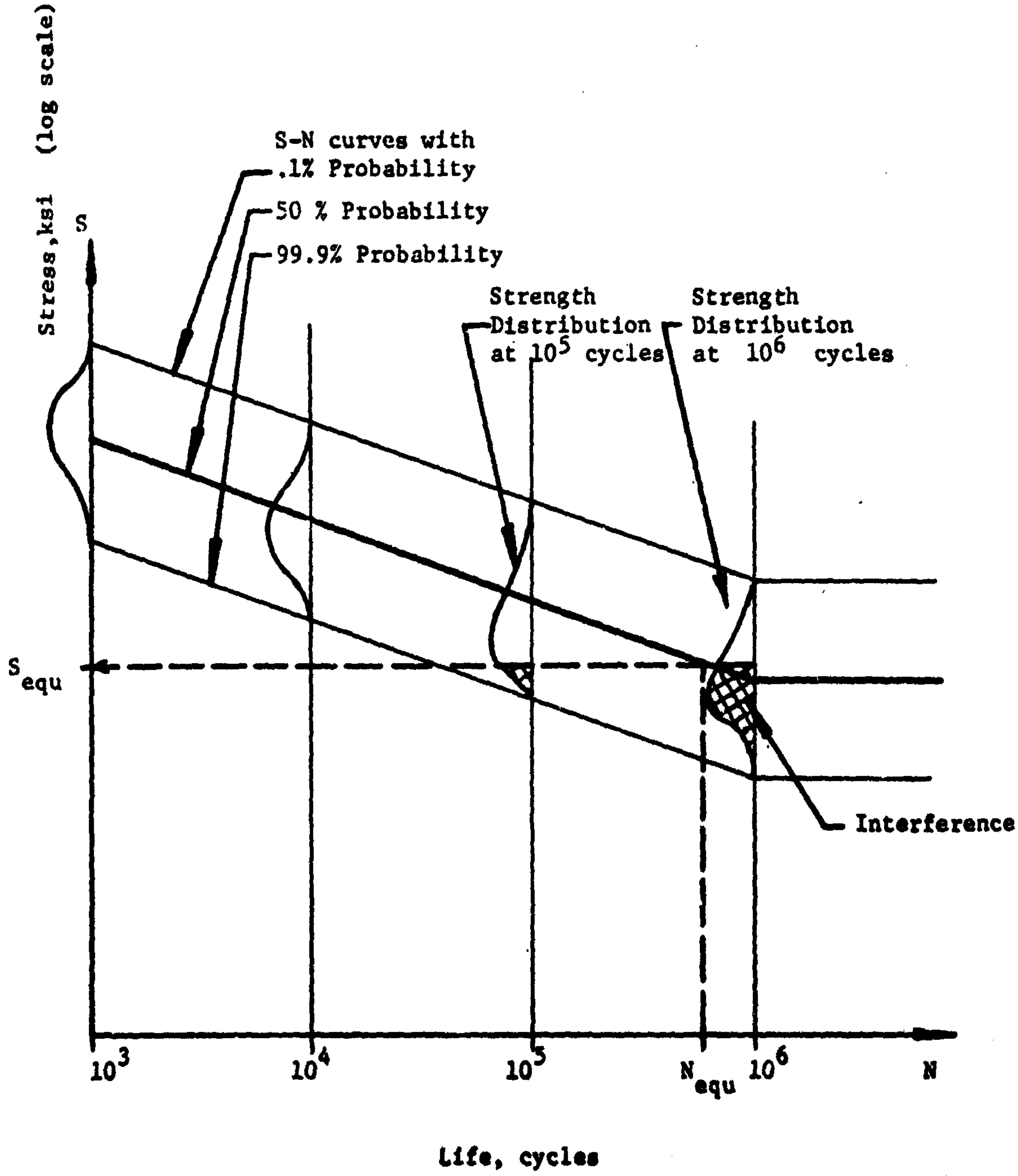


Figure 8.3 S-N Diagram Representing the Dependence of Interference on Life

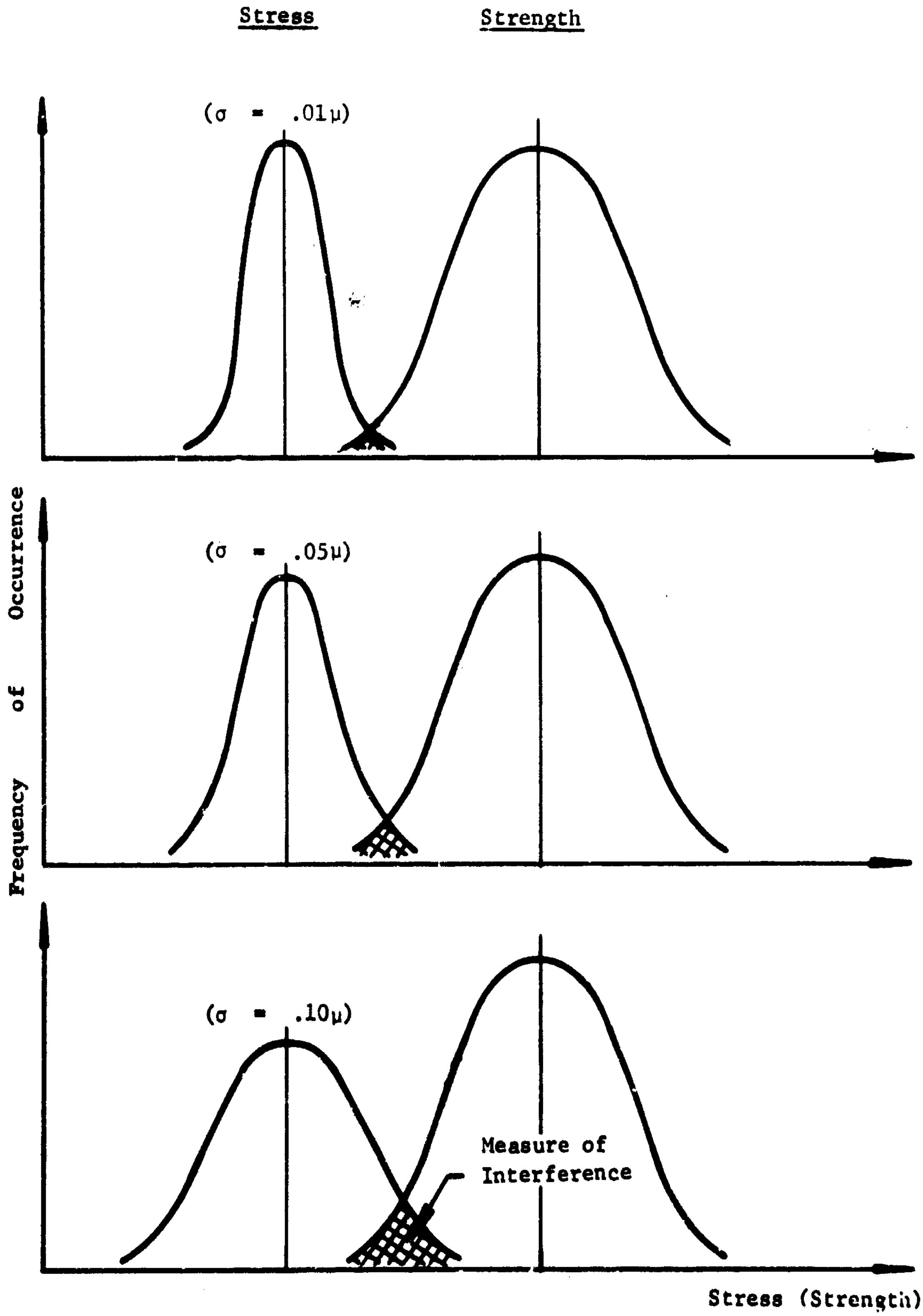


Figure 8.4 Interference of S_{equ} with Strength Distribution for Various Values of Standard Deviation

SECTION 9 APPLICATION OF INTERFERENCE THEORY TO DESIGN PROBLEMS

Once the parameters of the strength distribution (X_o,θ,b; or μ,σ; or β, M) and the stress distribution ($\mu = S_{equ}$ and $\sigma = K\mu$, where K represents a fraction of the average stress) are determined, as shown in Sections 6 and 7 respectively, the percent interference and consequently the reliability (Reliability= 1- Interference) can be computed with the aid of the tables in Appendix 2. The specific steps to be taken in solving particular design problems are illustrated by the following examples.

9.1 EXAMPLE PROBLEM NO. 1 (EFFECT OF STRESS CONCENTRATION ON RELIABILITY)

The present design for an aircraft part specifies the following:

Material:	2024 Aluminum S_u=70 ksi, S_y=50 ksi
Design Life:	10^6 cycles
Type of Loading:	Axial
Size:	.125" sheet
Surface Finish:	Electropolished
Stress Concentration Factor:	K_t = 2.4 (Hole)
Operating Temperature:	Room Temperature

An alternative design calls for reducing the stress concentration at the critical section, at additional cost, by milling an edge notch instead of drilling a hole. This alternative design reduces the theoretical stress concentration factor, K_t, to 1.5. Will the resultant reduction in stress concentration affect the reliability of the part?

9.1.1 Strength Parameters

The first step is to determine the strength distribution in terms of its parameters corresponding to the design conditions. From the table on Page 194 (Code No. 100), at 10^6 cycles the strength distribution of the present design is found to be:

Strength Distribution:	Weibull
Strength Parameters:	X_o = 13.76 ksi
	b = 1.808
	θ = 16.31 ksi

For the alternative design, the strength distribution at 10^6 cycles is found from the table on Page 194 (Code No. 102) to be:

Strength Distribution: Smallest Extreme Value
Strength Parameters: $\beta = .8348$
$M = 19.98$ ksi

9.1.2 Stress Parameters

In order to determine the parameters of the stress distributions ($\mu = S_{equ}$ and $\sigma = K\mu$), a prototype of each design was instrumented and the stress spectrums were recorded as shown in Columns 1 and 2 of Tables 9.1 and 9.2. To determine the equivalent stress (S_{equ}), Miner's rule is used. From the S-N curves of the material (Figure 9.1 and 9.2) the number of cycles to failure, N, corresponding to the stresses in Column 1 of Tables 9.1 and 9.2 are determined. These are shown in Column 3 of Tables 9.1 and 9.2.

Using Miner's Rule, as expressed in Equation (7.2), and the tabulated data in Table 9.1, N_{equ} is determined for the present design:

$$N_{equ} = 1 \times \frac{\sum n_i}{\sum \frac{n_i}{N_i}}$$

$$N_{equ} = 1 \times \frac{1035}{255.7\text{x}10^{-6}} = 4.05 \times 10^6 \text{ cycles}$$

From the S-N curve (Figure 9.1) the stress corresponding to $N_{equ} = 4.05 \times 10^6$ cycles is found to be $S_{equ} = 13.7$ ksi. Hence, the application of a completely reversed stress of 13.7 ksi can be substituted for the recorded stress spectrum in Columns 1 and 2 of Table 9.1. Similarly, using the data from Table 9.2 for the alternative design:

$$N_{equ} = 1 \times \frac{1035}{68.80\text{x}10^{-6}} = 1.51 \times 10^7 \text{ cycles}$$

From the S-N Curve (Figure 9.2) the stress corresponding to $N_{equ} = 1.51 \times 10^7$ cycles is found to be $S_{equ} = 13.5$ ksi.

In some engineering applications, the scatter in operating stresses is very small, therefore, the standard deviation of the equivalent stress can be assumed to be zero. In those engineering applications where the scatter in stress is appreciable, the standard deviation lies in the range:

$$0.01\mu \leq \sigma \leq 0.10\mu \ .$$

In the absence of any specific information, an average value of $\sigma = .05\mu$ can probably be assumed. For the present problem, interference will be calculated for the two cases: $\sigma = 0$ and $\sigma = .05\mu$.

Thus, the stress parameters for the present design are:

Case 1. $\mu = S_{equ} = 13.7$ ksi and $\sigma = 0$ and,

Case 2. $\mu = 13.7$ ksi and $\sigma = .05\mu = (.05)(13.7) = .685$ ksi.

PRESENT DESIGN

Stress Spectrum		Miner's Rule Data	
Completely* Reversed Axial Stresses, ksi	Number of Occurrences, N_i	Cycles to Failure, N_i	$\frac{n_i}{N_i}$
1	2	3	4
11.7	240	1.5×10^7	16.0×10^{-6}
12.5	217	9×10^6	24.1×10^{-6}
13.0	176	6.2×10^6	28.4×10^{-6}
13.8	150	3.9×10^6	38.4×10^{-6}
14.1	110	2.9×10^6	37.9×10^{-6}
14.9	75	1.8×10^6	41.6×10^{-6}
15.7	52	1.15×10^6	45.2×10^{-6}
15.9	20	1.05×10^6	19.0×10^{-6}
16.0	5	1.0×10^6	5.0×10^{-6}
	$\sum n_i = 1035$		$\sum \frac{n_i}{N_i} = 255.7 \times 10^{-6}$

Table 9.1 Stress and Life Data for Miner's Rule

***Actually, the stress was not completely reversed. It was reduced with the aid of Goodman Diagram to a completely reversed stress using the procedure given in Section 7.2.**

Stress Spectrum		Miner's Rule Data	
Completely* Reversed Axial Stresses, ksi	Number of Occurrences, n_i	Cycles to Failure, N_i	$\frac{n_i}{N_i}$
1	2	3	4
11.7	240	5.1×10^7	4.70×10^{-6}
12.5	217	3.0×10^7	7.24×10^{-6}
13.0	176	2.1×10^7	8.39×10^{-6}
13.8	150	1.3×10^7	11.52×10^{-6}
14.1	110	1.1×10^7	10.00×10^{-6}
14.9	75	7.2×10^6	10.40×10^{-6}
15.7	52	4.8×10^6	10.81×10^{-6}
15.9	20	4.4×10^6	4.55×10^{-6}
16.0	5	4.2×10^6	1.19×10^{-6}
	$\sum n_i = 1035$		$\sum \frac{n_i}{N_i} = 68.80 \times 10^{-6}$

Table 9.2 Stress and Life Data for Miner's Rule

***Actually, the stress was not completely reversed. It was reduced with the aid of a Goodman diagram to a completely reversed stress using the procedure given in Section 7.2.**

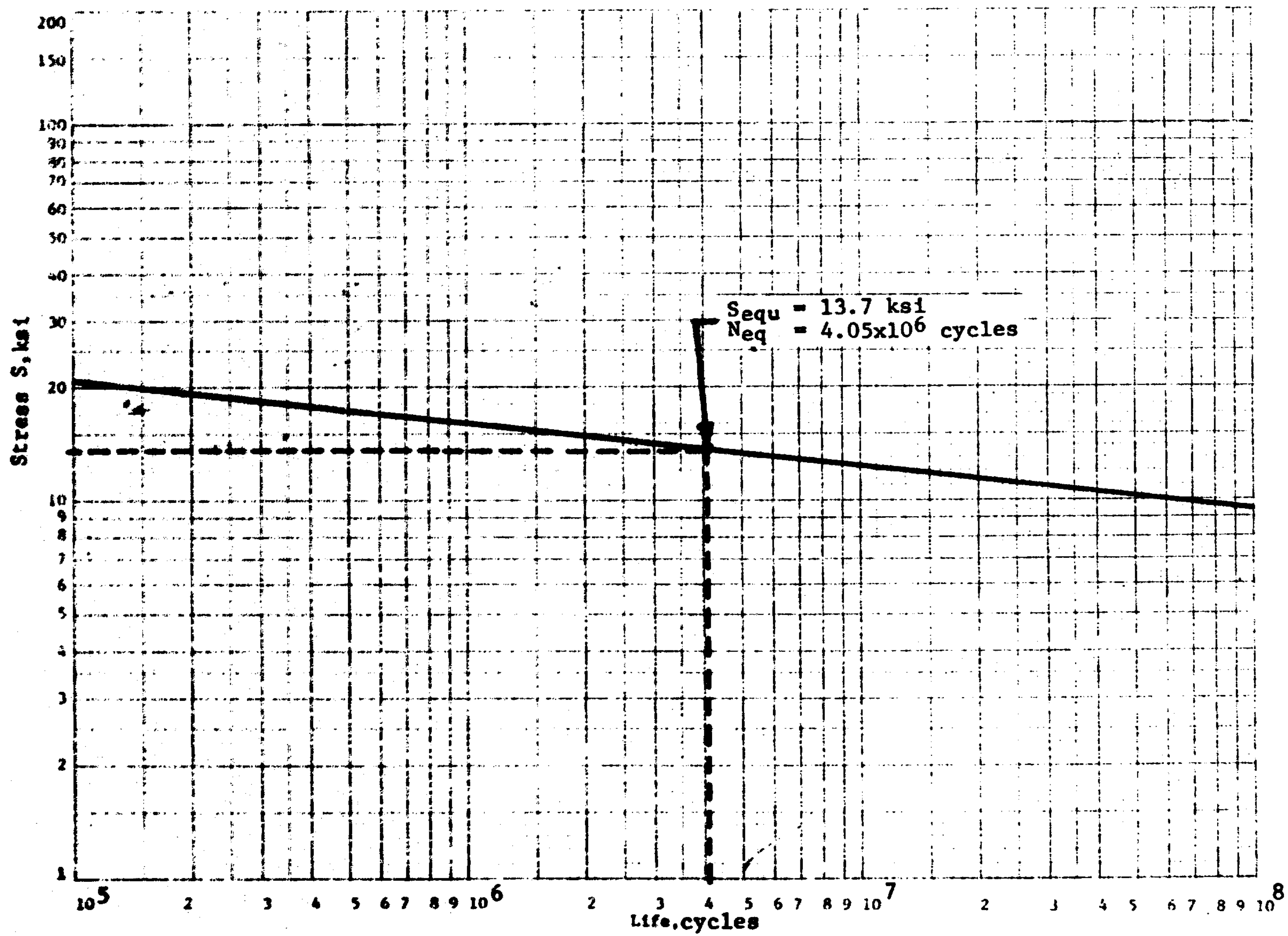


Figure 9.1 S-N Relationship for the Present Design

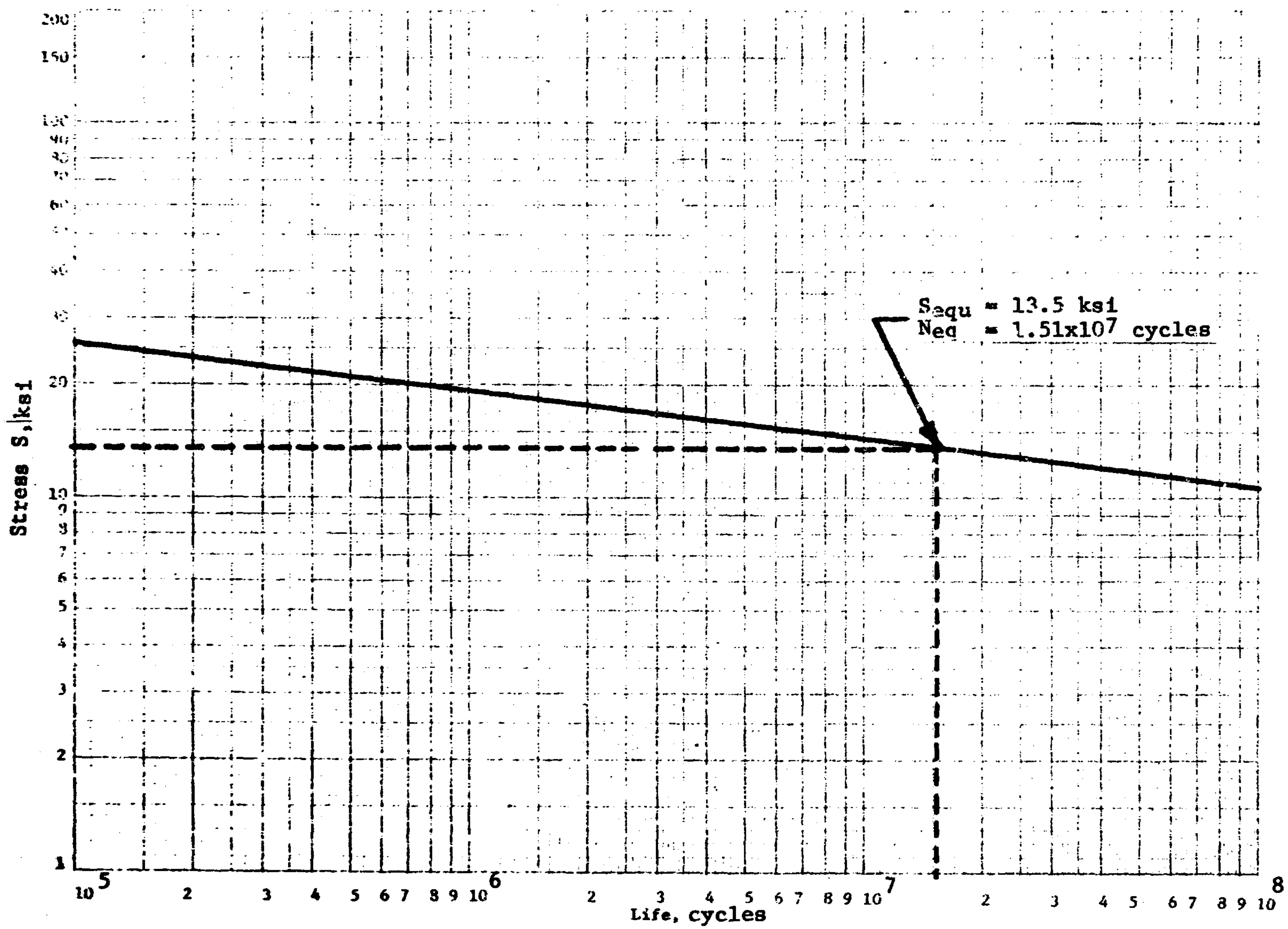


Figure 9.2 S-N Relationship for the Alternative Design

Similarly, the stress parameters for the <u>alternative design</u> are:

1. $\mu = S_{equ} = 13.5$ ksi and $\sigma = 0$

and 2. $\mu = 13.5$ ksi and $\sigma = .05\mu = (.05)(13.5) = .675$ ksi.

9.1.3 Percent Interference

Once the strength and stress distribution parameters are determined, the Percent Interference and the Reliability (%Reliability = 100-% Interference) can be determined.

Case (1) when stress standard deviation (σ) = 0:

For this case where stress is Normally distributed with $\mu = S_{equ}$ and $\sigma = 0$, the percent interference can be determined as follows:

Present Design

For Weibull distributed strength,

$$\text{Interference } F(x) = 1 - e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^b} = \text{shaded area under Figure 8.1}$$

where $x = S_{equ} = 13.70$ ksi

$X_o = 13.76$ ksi

$b = 1.808$

$\theta = 16.31$ ksi

$$F(x) = 1 - e^{-\left(\frac{13.70-13.76}{16.31-13.76}\right)^{1.808}}$$

$$= 0$$

Percent Interference = 0%

It can also be seen, from Figure A-2.1 in Section A-2.2.1, that when S_{equ} is less than X_o there is no Interference. In the case when S_{equ} is greater than X_o, the Percent Interference can be determined as:

Find,

$$X = \left(\frac{S_{equ}-X_o}{\theta - X_o}\right)^b$$

Corresponding to the value of X read interference F(x) from the table in Section A-2.2.1, Pages 371 or 372.

Alternative Design

For Smallest Extreme Value distributed strength,

$$\text{Interference } F(x) = 1 - e^{-e^{+\beta(x-M)}} = \text{shaded area under Figure 8.1}$$

where $x = S_{equ} = 13.50$ ksi

$\beta = .8348$

$M = 19.98$

$$F(x) = 1 - e^{-e^{.8348(13.50-19.98)}}$$

$$= 1 - e^{-e^{-5.404}} = 1 - e^{-.0045}$$

$$= .0045$$

Percent Interference = .45%

This can also be read directly from the table in Section A-2.5.1, Page 419.

$$\text{Find } X = -\beta(S_{equ}-M) = -.8348\ (13.50-19.98)$$

$$= 5.404$$

Corresponding to X = 5.404 read interference F(x) = .0045 from the above table. Therefore, Percent Interference = .45%.

Case (2) when stress standard deviation (σ) $\neq 0$: (in this case $\sigma = .05\mu$)

For this case where stress is Normally distributed with $\sigma \neq 0$, additional interference parameters must be calculated to determine the percent interference.

Present Design

Strength (Weibull)	Stress (Normal)
$X_o = 13.76$ ksi	$\mu = S_{equ} = 13.70$ ksi
$b = 1.808$	$\sigma = 0.05\mu$
$\theta = 16.31$ ksi	$= 0.685$ ksi

For the above data, interference parameters C, A, and B(x) to be used in the interference tables were computed.

$$C = \frac{\theta - X_o}{\sigma} = \frac{16.31-13.76}{0.685} = 3.72$$

$$A = \frac{X_o - \mu}{\sigma} = \frac{13.76-13.70}{0.685} = .0875$$

$$B(x) = b = 1.808$$

From the tables in Section A-2.2.2 on Pages 388 and 390, the interference value corresponding to these parameters is read using linear interpolation (for a higher order and more accurate interpolating technique, see Section A-2.1).

Interference = .0398

or Percent Interference = 3.98%

Alternative Design

Strength (S.E.V.)	Stress (Normal)
$\beta = .8348$	$\mu = S_{equ} = 13.50$ ksi
$M = 19.98$ ksi	$\sigma = .05\mu = .675$ ksi

For the above data, interference parameters α and γ to be used in the interference tables are computed.

$$\alpha = \beta\sigma = (.8348)(.675) = .564$$

$$\gamma = \beta(S_{equ}-M) = (.8348)(-6.48) = -5.4$$

From the table in Section A-2.5.2 on Page 422, the interference value corresponding to these parameters is read using linear interpolation (for a higher order and more accurate interpolating technique, see Section A-2.1).

Interference = .0059

or Percent Interference = .59%

A summary of the results is given in Table 9.3.

Thus, the reduction in the stress concentration factor should, in effect, result not only in lower stress but also in somewhat higher reliability.

	Material	Theoretical Stress Concentration Factor, K_t	Strength Distribution and its Parameters	Equivalent Stress S_{equ}, ksi	% Interference at 10^6 cycles		% Reliability at 10^6 cycles (100-%Interfer.)	
					$\sigma=0$	$\sigma=.05\mu$	$\sigma=0$	$\sigma=.05\mu$
Present Design	2024 Aluminum	2.4	<u>Weibull</u> X_o = 13.76 ksi b = 1.808 θ = 16.31 ksi	13.7	0	3.98	100.00	96.02
Alternative Design	2024 Aluminum	1.5	<u>S.E.V.</u> β = .8348 M = 19.98 ksi	13.5	.45	.59	99.55	99.41

Table 9.3 Effect of Stress Concentration Factor on Reliability at 10^6 Cycles

9.2 EXAMPLE PROBLEM NO. 2 (EFFECT OF TEMPERATURE ON RELIABILITY)

A part in service has been performing satisfactorily under the following conditions:

Material:	Ti-4Al-3Mo-1V; .125" sheet; S_u = 16.0 ksi S_y = 13.2 ksi
Loading:	Axial
Surface Finish:	Ground
Stress Concentration Factor at Critical Section:	$K_t = 1.0$
Operating Temperature:	400°F
Reliability Requirement:	99.99% at 5×10^6 cycles
Stress Parameters for the Critical Section:	μ = 28.2 ksi σ = 1.41 ksi (Previously determined)

If the efficiency of the system can be increased by increasing the operating temperature, how will the reliability of the component part be affected if the temperature is increased to 600°F, 800°F, and the stress parameters remain the same?

9.2.1 Strength Parameters

From the table on Page 303 (Code Nos. 586 and 587) the strength parameters for 600°F and 800°F at 5×10^6 cycles are:

600°F

Strength Distribution: Largest Extreme Value

Strength Parameters: β = .2066

M = 40.79 ksi

800°F

Strength Distribution: Largest Extreme Value

Strength Parameters: β = .2836

M = 28.74 ksi

9.2.2 Stress Parameters

The stress parameters have been previously determined and are:

Stress Distribution: Normal

Stress Parameters: $\mu = S_{equ} = 28.2$ ksi

$\sigma = 1.41$ ksi

9.2.3 Percent Interference

With the strength and stress distribution parameters established, the percent interference can be determined at the various temperatures:

600°F

Strength Distribution: Largest Extreme Value (β, M)

Stress Distribution: Normal (μ, σ)

Interference Parameters:

$$\alpha = \beta\sigma = .2066\ (1.41) = .292$$

$$\gamma = \beta(\mu - M) = .2066\ (28.2 - 40.79) = -2.6$$

Using parameters (α, γ), the interference at 5×10^6 cycles is obtained by linear interpolation from the table in Section A-2.4.2 on Page 411(For a more accurate interpolation method, see Section A-2.1).

Interference = .00092

Percent Interference = .092%

Percent Reliability = (100-% Interference)

= 99.908%

800°F

Strength Distribution: Largest Extreme Value(β, M)

Stress Distribution: Normal (μ, σ)

Interference Parameters:

$$\alpha = \beta\sigma = (.2836)(1.41) = .400$$

$$\gamma = \beta(\mu - M) = .2836\ (28.20 - 28.74) = -.153$$

Using parameters (α,γ), the interference at 5×10^6 cycles is obtained by linear interpolation from the table in Section A-2.4.2 on Page 411 (For a more accurate interpolation method, see Section A-2.1).

$$\text{Interference} = .33426$$

$$\text{Percent Interference} = 33.426\%$$

$$\text{Percent Reliability} = (100-\%\ \text{Interference})$$

$$= 66.574\%$$

A summary of the results is given in Table 9.4.

Thus, an increase in the operating temperature from 600°F to 800°F results in an appreciable reduction in reliability.

Material	Temperature °F	Strength Distribution and its Parameters	Stress Distribution and its Parameters	Percent Interference at 5 x 10^6 cycles	Percent Reliability at 5 x 10^6 cycles (100-%Interference)
Ti-4 Al-3 Mo-1 V Sheet	400	Present Operating Temperature	Normal $\mu = S_{equ}$ $= 28.2$ ksi $\sigma = 1.41$ ksi	.010	99.990
	600	L.E.V. $\beta = .2066$ $M = 40.79$ ksi		.092	99.908
	800	L.E.V. $\beta = .2836$ $M = 28.74$ ksi		33.426	66.574

Table 9.4 Effect of Temperature on Reliability at 5 x 10^6 cycles.

CONCLUSIONS AND RECOMMENDATIONS

1. A method was developed for employing Stress-Strength Interference Theory as a practical engineering tool to be used for designing and quantitatively predicting the reliability of mechanical parts and components, made of non-ferrous materials, subjected to mechanical loading.

2. This method is based on considerable empirical data gathered (Appendix 1) and it also has sound theoretical basis (Appendix 3). This method eliminates the concept of a Factor of Safety and substitutes Percent Interference (Probability of Failure). Tables of interference values are given in Appendix 2 for a variety of stress and strength conditions.

3. Although a great deal of data was gathered and analyzed in the course of the present study, no data were found to permit the establishment of confidence intervals on the probability of interference.

4. In our past investigation(1), because of the limitations of the graphical approach employed, this method was limited to the following three cases:

Stress Distribution	Strength Distribution
Normal	Normal
Normal	Weibull
Weibull	Weibull

In the present investigation, based on the computer approach, the method was extended to the following three additional cases:

Stress Distribution	Strength Distribution
Normal	Weibull (Extended-see Section 4.2)
Normal	Largest Extreme Value
Normal	Smallest Extreme Value

5. For these combinations of stress and strength distributions, interference values were calculated by an Integral Method and these are tabulated in Appendix 2. These values were found to be highly non-linear. Therefore, for the purpose of interpolating these values in a given table or between the tables, a higher order interpolation (Section A-2.1) should be used.

6. A computer approach (referred to above) was developed for determining the statistical distribution function of fatigue strength at a given life. When the raw data (conventional S-N type data) were fed into this computer program, the computer printed the correlation coefficient (a degree of fit) and the parameters for Normal, Weibull, Largest Extreme Value and Smallest Extreme Value distributions, for any given set of strength data. This method has the advantage of high accuracy and time saving over the graphical method used in the previous investigation.(1)

7. The effect of type of loading, surface finish, stress concentration, heat treatment, temperature, environment and other factors (Section 4.4) on the statistical distribution function of fatigue strength of various non-fer-

rous materials was studied. These effects were expressed in terms of the distribution parameters which were tabulated (Appendix 1, pages 155-350) and the representative ones plotted (Section 6.7, pages 53-117).

8. In most cases, the effect of the factors listed under item 7 above was to change the distribution function. That is, for a given material and surface finish the distribution function might be Weibull but for the same material and different surface finish, the distribution could change to Largest Extreme Value. (This refers to the best fitting distribution for each particular material and set of conditions, as described in Section 6.6). The only exception is the effect of life. Life was found to retain the same distribution and change only the parameters of that distribution (see the basic assumption given in Section 6.2 on page 31).

9. For the non-ferrous materials studied, the effect of life on the fatigue strength distribution parameters is shown in the table below:

Fatigue Strength Distribution	Distribution Parameters	Effect of Life on Distribution Parameters
Weibull	X_o	Linearly decreases with life on log-log scale
	Θ	Linearly decreases with life on log-log scale
	b	Increases or decreases with life depending on conditions
Normal	μ	Linearly decreases with life on log-log scale
	σ	Decreases with life
Largest Extreme Value	M	Linearly decreases with life on log-log scale
	β	Increases with life
Smallest Extreme Value	M	Linearly decreases with life on log-log scale
	β	Increases with life

10. As to the problem of stress, the stress distribution was investigated in more detail than in the previous study(1) but no additional information was located.

11. In order to verify the validity of the Interference Technique developed in the present study, it should be checked against an actual life situation. That is, percent interference should be computed for an actual engineering problem. These results then should be compared with actual service failures.

REFERENCES

1. Lipson, C., Sheth, N.J., Disney, R.L., "Reliability Prediction - Mechanical Stress/Strength Interference. Rome Air Development Center, Griffiss Air Force Base: Final Report No. RADC-TR-66-710, March 1967.

2. Lipson, C., Sheth, N.J., Pittman, R.B., "Designing Engineering Experiments," Engineering Summer Conference, Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan, May 1968.

3. Lipson, C., Kerawalla, J., and Mitchell, L., Engineering Applications of Reliability. Engineering Summer Conference, Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan, 1963.

4. Grover, H.J., Gordon, S.A., and Jackson, L.R., "Fatigue of Metals and Structures," Department of Navy, U.S. Government Printing Office, 1960.

5. Heywood, R.B., Designing Against Fatigue. London: Chapman and Hall, Ltd., 1962.

6. Lipson, C. and Juvinall, R.C., Handbook of Stress and Strength, New York: The Macmillan Co., 1963.

7. Johnson, Leonard G., "GMR Reliability Manual." GMR-302, 1960. Research Laboratories, General Motors Corporation.

8. Gumbel, Emil J., "Statistical Theory of Extreme Values and Some Practical Applications," National Bureau of Standards, Applied Mathematics Series 33, 1954.

9. National Bureau of Standards, "A Guide to Tables of the Normal Probability Integral." Applied Mathematics Series, #21, Washington: U.S. Government Printing Office, 1952.

10. Miner, M.A., "Cumulative Damage in Fatigue." Journal of Applied Mechanics, Volume 12, 1945.

11. Miner, M.A., "Estimation of Fatigue Life with Particular Emphasis on Cumulative Damage." Chapter 12 of Metal Fatigue, edited by Sines, George, and J.L. Waisman, New York: McGraw-Hill Book Co., 1959.

12. Dolan, T.J.; Richart, F.E.; and Work, C.E., "Influence of Fluctuation in Stress Amplitude on the Fatigue of Metals." ASTM Proceedings, Vol. 49, 1949.

13. Richart, F.E.; and Newmark, N.M., "An Hypothesis for the Determination of Cumulative Damage in Fatigue." ASTM Proceedings. Vol. 48. 1948.

14. Grover, H.J.; Bishop, S.M.; and Jackson, L.R., "Fatigue Strength of Aircraft Materials: Axial Load Fatigue Tests on Unnotched Sheet Specimens of 24S-T3 and 75S-T6 Aluminum Alloys and of SAE 4130 Steel." NACA Tech. Note 2324, 1951.

15. Harris, J.P., and Lipson, C., "Cumulative Damage Due to Spectral Loading" Aerospace Reliability and Maintainability Conference, SAE, ASME, AIAA Conference Proceedings, July, 1964.

16. Henrici, P., "Elements of Numerical Analysis." John Wiley and Sons: March 1967.

BIBLIOGRAPHY

1. American Society of Testing and Materials, A Guide for Fatigue Testing and the Statistical Analysis of Fatigue Data. Special Technical Publication No. 91-A (Second Edition), 1963.

2. Bazovsky, I., Reliability Theory and Practice. Prentice Hall Inc., Space Technology Series, Chapter 15: "Component Failure Rates at System Stress Levels."

3. Bird, G.T., "On the Basic Concepts of Reliability Prediction." (Monte Carlo) p. 54, Seventh National Symposium on Reliability and Quality Control, 1961.

4. Bowker, A.H. and Lieberman, G.J., Engineering Statistics. Prentice-Hall Inc., New Jersey: 1959.

5. Corten, H.T., "Application of Cumulative Fatigue Damage Theory to Farm and Construction Equipment." SAE Paper 735 A, September, 1963.

6. Corten, H.T., "Overstressing and Understressing in Fatigue, (Cumulative Fatigue Damage)." ASME Handbook, Metals Engineering-Design, Second Edition, 1965.

7. Corten, H.T. and Dolan, T.J., "Cumulative Fatigue Damage," The International Conference on Fatigue of Metals, I.M.E. and ASME, September 10-14, 1956.

8. Croxten, F.E. and Cowden, D.J., Practical Business Statistics, Prentice-Hall, New York, 1965.

9. Dieter, G.E. and Mehl, R.F., "Investigation of Statistical Nature of Fatigue of Metals." NACA Technical Note No. 3019, September 1953.

10. Dolan, T.J. and Corten, H.T., "Progressive Damage Due to Repeated Loading." WADC Symposium, Fatigue in Aircraft Structures, August, 1959.

11. Dolan, T.J.; Richart, R.E.; and Work, C.E., "Influence of Fluctuations in Stress Amplitude on the Fatigue of Metals." ASTM Proceedings, Vol. 49, 1949.

12. Forrest, P.G., Fatigue of Metals. New York: Pergamon Press, 1962.

13. Freudenthal, A.M., Fatigue Sensitivity and Reliability of Mechanical Systems. SAE Paper 459 A, January, 1962.

14. Freudenthal, A.M. and Gumbel, E.J., "Distribution Functions for the Prediction of Fatigue Life and Fatigue Strength," The International Conference on Fatigue of Metals. IME and ASME, 1956.

15. Freudenthal, A.M. and Heller, R.A., "On Stress Interaction in Fatigue and a Cumulative Damage Role, Part 1: 2024 Aluminum and SAE 4340 Steel Alloys." WADC Technical Report 58-69, June, 1958.

16. Freund, John E., Mathematical Statistics, New York: Prentice Hall, 1965.

17. Grey, E.F., "Statistical Methods as Design Tools." Eighth National Symposium on Reliability and Quality Control. pp. 70-71, 1962.

18. Grover, H.J.; Gordon, S.A.; and Jackson, L.R., Fatigue of Metals and Structures. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.: June, 1966.

19. Gumbel, Emil J., "Statistical Theory of Extreme Values and Some Practical Applications," National Bureau of Standards, Applied Mathematics Series 33, 1954.

20. Harris, J.P. and Lipson, C., "Cumulative Damage Due to Spectral Loading." Aerospace Reliability and Maintainability Conference. SAE, ASME, AIAA Conference Proceedings, July, 1964.

21. Haugen, E.B., "Statistical Methods for Structural Reliability Analysis." Appendix p. 110-121, Tenth Symposium on Reliability and Quality Control. pp. 97-109, 1964.

22. Haviland, R.P., "Introduction to Theory of Reliability." SAE Paper 343 D, 1961.

23. Henrici, P., "Elements of Numerical Analysis." John Wiley and Sons: March 1967.

24. Heywood, R.B., Designing Against Fatigue. London: Chapman and Hall, 1962

25. Johnson, Leonard G., "GMR Reliability Manual." GMR-302, 1960. Research Laboratories, General Motors Corporation.

26. Kaechele, L.E., "Designing to Prevent Fatigue Failures." Rand Report P-3022. February, 1965.

27. Kaechele, L.E., "Probability and Scatter in Cumulative Fatigue Damage." Rand Report, RM-3688-PR. December, 1963.

28. Kaechele, L.E., "Review and Analysis of Cumulative Damage Theories." Rand Report, RM-3650-PR. September, 1963.

29. Kececioglu, D. and Cormier, D., "Designing a Specified Reliability Directly into a Component." Aerospace Reliability and Maintainability Conference, Washington, D.C.: pp. 546-564, 1964.

30. Kullback, S., "The Distribution Laws of the Differences and Quotient of Variables Distributed in Pearson Type III Laws." The Annals of Mathematical Statistics. Volume VII, Number 1, March 1936, pp. 51-53.

31. Langer, B.F., "Fatigue Failure from Stress Cycles of Varying Amplitude." Transactions, ASME. Volume 59, p. A-160, 1937.

32. Lipson, C. and Juvinall, R.C., Handbook of Stress and Strength. New York: The Macmillan Company, 1963.

33. Lipson, C.; Kerawalla, J.; and Mitchell, L., Engineering Applications of Reliability. Engineering Summer Conference, Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan, 1963.

34. Lipson, C. and Noll, G.C., "Design Practice." ASME Handbook, Metals Engineering Design, Second Edition, 1965.

35. Lipson, C.; Sheth, N.J.; Disney, R.L., "Reliability Prediction-Mechanical Stress/Strength Interference. Rome Air Development Center, Griffis Air Force Base: Final Report No. RADC-TR-66-710, March 1967.

36. Lipson, C.; Sheth, N.J.; Pittman, R.B., "Designing Engineering Experiments," Engineering Summer Conference, Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan, May 1968.

37. Lipson, C.; Sheth, N.J.; and Sheldon, D.B., "Reliability and Maintainability in Industry and the Universities." Fifth Reliability and Maintainability Conference. Volume 5, 1966.

38. Little, R.E., "Design of Fatigue Experiments in Research and Development." University of Michigan #6637-118, Engineering Summer Conferences, Ann Arbor, Michigan, 1966.

39. Little, R.E., Multiple Specimen Testing and the Associated Fatigue Strength Response. The University of Michigan, Ann Arbor, Michigan: January, 1966.

40. Liu, H.W. and Corten, H.T., "Fatigue under Varying Stress Amplitude." NASA Technical Note D-647. November, 1960.

41. Lloyd, David K. and Lipow, Myron, Reliability: Management, Methods and Mathematics. Englewood Cliffs, N.J.: Prentice-Hall, 1962.

42. Miner, M.A., "Cumulative Damage in Fatigue." Journal of Applied Mechanics. Volume 12, No. 3, p. A-159, September, 1945.

43. Mittenbergs, A.A., "Fundamental Aspects of Mechanical Reliability." Mechanical Reliability Concepts. ASME Design Engineering Conference, New York: May 17-20, 1965.

44. National Bureau of Standards, "A Guide to Tables of the Normal Probability Integral." Applied Mathematics Series, #21, Washington: U.S. Government Printing Office, 1952.

45. National Bureau of Standards Handbook 91, "Experimental Statistics," August 1, 1968.

46. National Bureau of Standards, "Probability Tables for Analysis of Extreme-Value Data," Applied Math Series, #22, Washington; U.S. Government, 1953.

47. Pearson, K; Stouffer, S.A.; and David, F.N., "Further Applications in Statistics of the $T_m(x)$ Bessel Function." Biometrika. Volume XXIV, Parts III, IV, pp. 293-350, November 1932.

48. Pearson, K. (Editor), Tables of the Incomplete Beta Function. Biometrika Office, Cambridge Office, Cambridge University Press, 1948.

49. Pieruschka, E., Principles of Reliability. Prentice-Hall, Inc., pp. 99-115, 336-340, 1963.

50. Pirie, Alexandre I., "Linear Regression Analysis (Two Variables)," Statistics for the Engineer, SP-250, Society of Automotive Engineers, New York 1963.

51. Popp, H.G., "Reliability Through Statistical Material Property Definition." SAE Paper 580B. October, 1962.

52. Sines, G. and Waisman, J.L., Metal Fatigue. New York: McGraw-Hill, 1959.

53. Stulen, F.B. and Cummings, H.N., "Statistical Analysis of Fatigue Data." Proceedings for Short Course in Mechanical Properties of Metals. (Marin, H.U., Editor). The Pennsylvania State University, Department of Engineering Mechanics, 1958.

54. Weibull, W., Fatigue Testing and Analysis of Results. New York: Pergamon Press, 1961.

55. Weibull, W., "Statistical Distribution Function of Wide Applicability." Journal of Applied Mechanics. p. 293, September 18, 1951.

56. Weibull, W., "Statistical Representation of Fatigue Failures in Solids." Royal Institute of Technology Transactions. Stockholm: Volume 27, No. 49,

57. Wilkine, E.W.C., Cumulative Damage in Fatigue. IUTAM Colloquium on Fatigue Springer, Stockholm: p. 321, 1956.

APPENDIX 1 TABLES OF THE DISTRIBUTION PARAMETERS OF FATIGUE STRENGTH

A-1.1 INDEX TO DISTRIBUTION PARAMETERS FOR VARIOUS NON-FERROUS MATERIALS

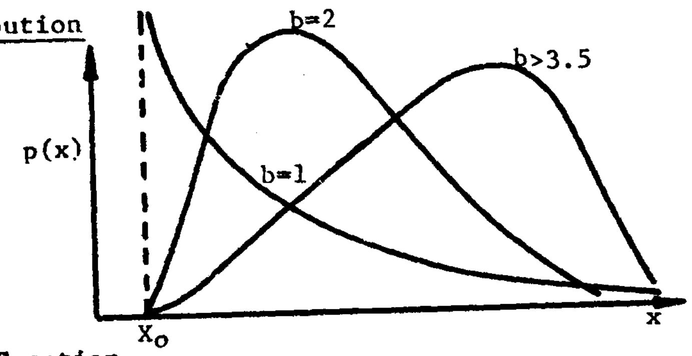
TITANIUM ALLOYS

A-1.2 DISTRIBUTION FUNCTIONS AND THEIR PARAMETERS USED IN TABLES

A-1.2.1 Weibull Distribution

Density Function

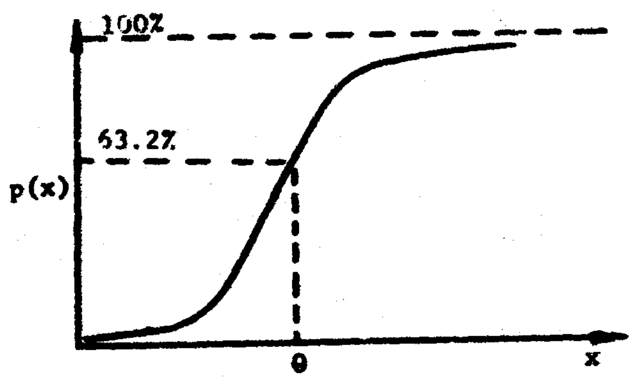
$$p(x) = \frac{b}{\theta - X_o}\left(\frac{x-X_o}{\theta-X_o}\right)^{b-1} e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^b}$$



Cumulative Distribution Function

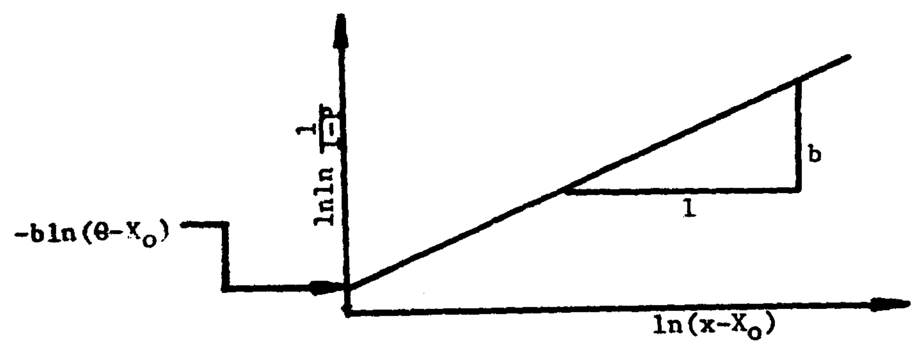
Non-Linear Form

$$P(x) = 1 - e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^b}$$



Linear Form

$$\ln\ln \frac{1}{1-P} = b\,[\ln (x-X_o)] + [-b \ln (\theta-X_o)]$$



b is the Weibull Slope (slope of the linear form of the distribution).

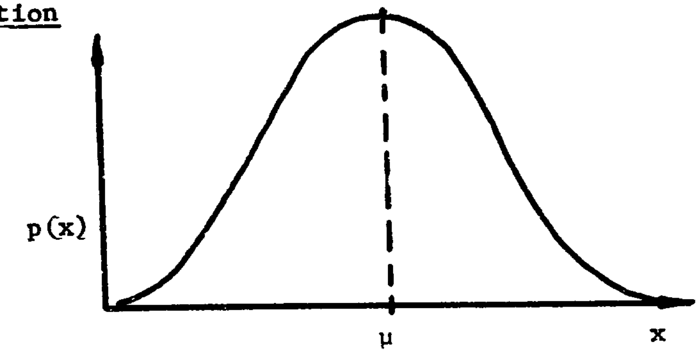
θ is the characteristic strength (where 63.2% of the population have fatigue strengths less than or equal to this value).

X_o is the lower bound of fatigue strength.

A-1.2.2 Normal Distribution

Density Function

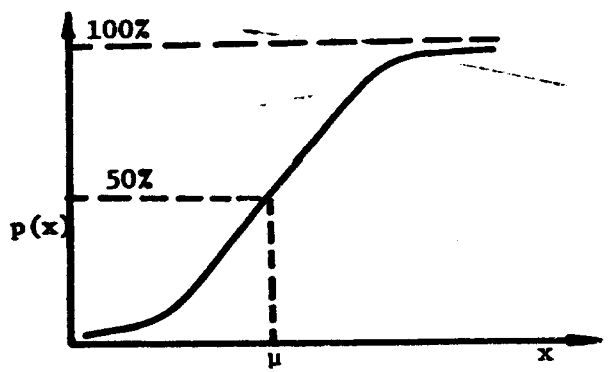
$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$



Cumulative Distribution Function

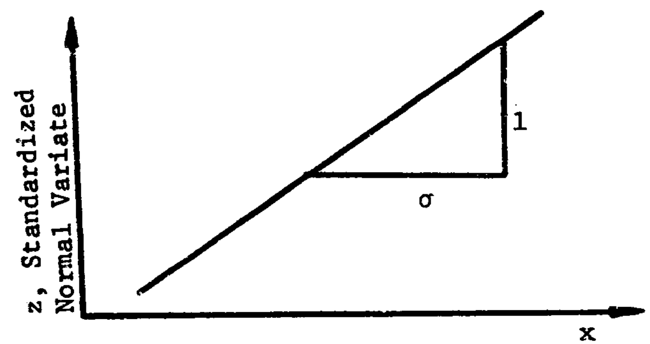
Non-Linear Form

$$P(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} \sigma e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$



Linear Form

$$z = \left(\frac{1}{\sigma}\right) x - \frac{\mu}{\sigma}$$



μ is the population mean (an average value).

σ is the standard deviation (a measure of scatter).

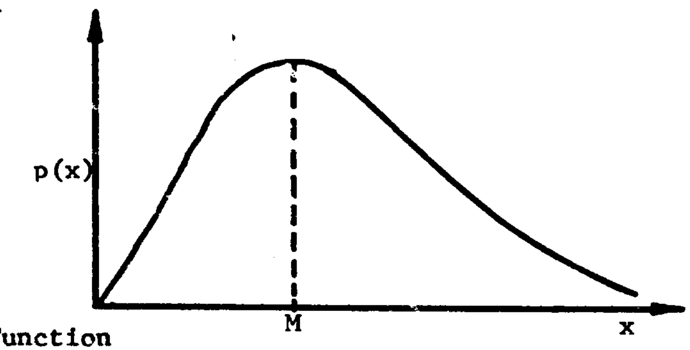
z is the standardized normal variate (number of standard deviations from the mean).

A-1.2.3 Largest Extreme Value Distribution

Density Function

$$p(x) = \beta\, e^{-\beta(x-M)-e^{-\beta(x-M)}}$$

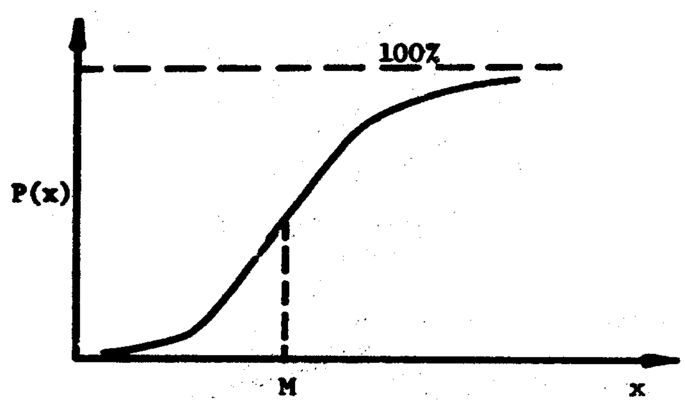
$$= \beta\, e^{-\beta(x-M)} \cdot e^{-e^{-\beta(x-M)}}$$



Cumulative Distribution Function

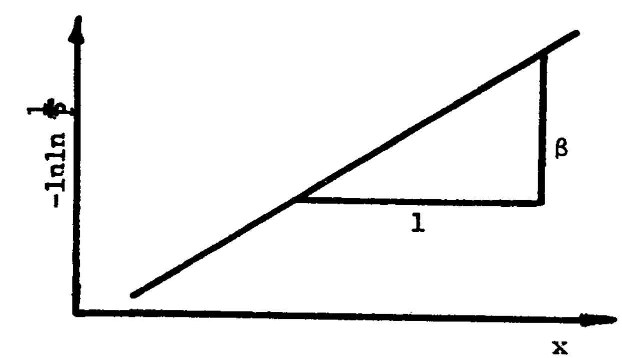
Non-Linear Form

$$P(x) = e^{-e^{-\beta(x-M)}}$$



Linear Form

$$-\ln\ln\frac{1}{P} = \beta x - \beta M$$



β is the intensity function (slope of the linear form of the distribution).

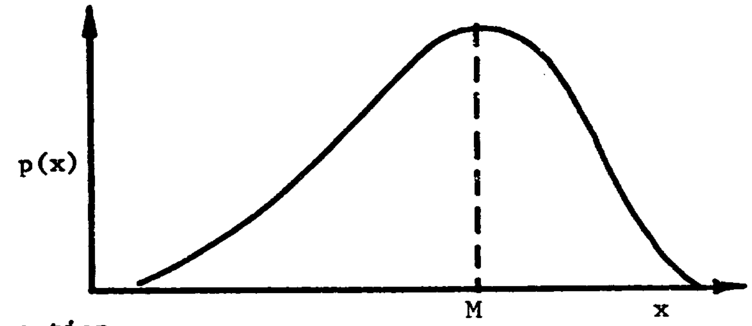
M is the mode (the most probable value).

A-1.2.4 Smallest Extreme Value Distribution

Density Function

$$p(x) = \beta e^{\beta(x-M)} - e^{\beta(x-M)}$$

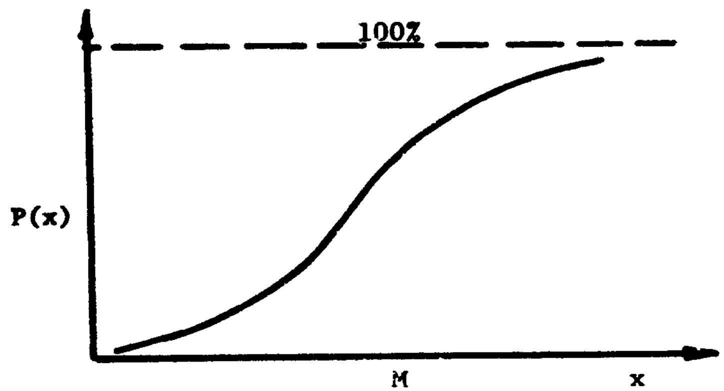
$$= \beta e^{\beta(x-M)} \cdot e^{-e^{\beta(x-M)}}$$



Cumulative Distribution Function

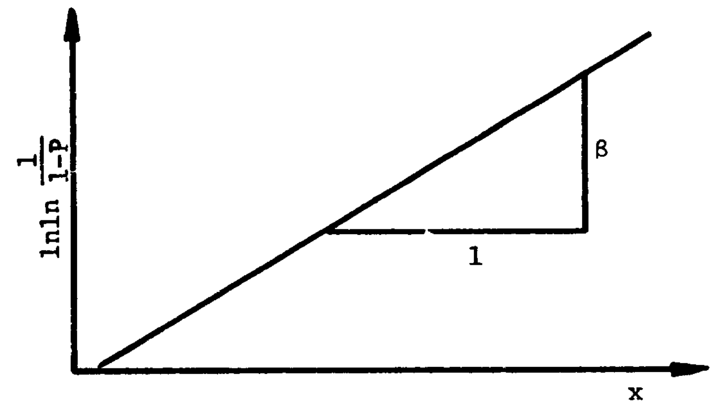
Curvilinear Form

$$P(x) = 1 - e^{-e^{\beta(x-M)}}$$



Linear Form

$$\ln\ln \frac{1}{1-P} = \beta x - \beta M$$



β is the intensity function (slope of the linear form of the distribution).

M is the mode (the most probable value).

A-1.3 LIST OF ABBREVIATIONS AND SYMBOLS USED IN TABLES

A.C. or AC	Air Cooled	Machin.	Machined
Ann. or Anneal	Annealed	M.P. or MP	Mechanical Polishing
D.G.	Diamond Ground	O.Q. or OQ	Oil Quenched
Dist.	Statistical Distribution Function	Param.	Distribution Parameter
E.P.	Electropolished	Pe	Peening (Shot Peening)
F.C. or FC	Furnace Cooled	ppm	Parts per Million
Freq.	Frequency, Cycles per Second	RMS	Root-Mean-Squares (Micro-inches)
gr.	grit or grain	S.E.V.	Smallest Extreme Value Distribution
H.F.	Hand Finished	Sh.E.	Shaped Edges
Ho-N	Hole Notch	Sol. H.T.	Solution Heat Treated
H-Roll	Hot Rolled	SP	Specimen Configuration
H.T. or HT	Heat Treated	S.R.	Surface Rolled
K_t	Theoretical Notch Factor	S_u	Ultimate Tensile Strength
L.E.V.	Largest Extreme Value Distribution	S_y	Yield Strength in Tension
Longi.	Longitudinal	Temp.	Temperature, °F
Long Transv.	Long Transverse	Transv.	Transverse
LTB	Lathe Turned or/and Bored	W.Q. or WQ	Water Quenched

A-1.4 COMPOSITION OF THE NON-FERROUS MATERIALS

I. ALUMINUM ALLOYS

Alloy	Percent Composition	
1. 1100 ALUMINUM	99.7 Al	Nominal
2. 5 Mg ALUMINUM	.21 Fe, .58 Si, 5.02 Mg, .26 Mn, Balance Al	Actual
3. 355 ALUMINUM	5 Si, 1.3 Cu, .5 Mg, Balance Al	Nominal
4. 7.5 Zn - 2.5 Mg ALUMINUM	7.5 Zn, 2.5 Mg, Balance Al	Nominal
5. M-257 ALUMINUM	Not Reported	
6. M-276 ALUMINUM	Not Reported	
7. 2014 ALUMINUM	4.46 Cu, .43 Fe, .95 Si, .8 Mn, .44 Mg, .072 Zn, Balance Al	Nominal
8. 2014 ALCLAD ALUMINUM	4.46 Cu, .43 Fe, .95 Si, .8 Mn, .44 Mg, .072 Zn, Balance Al	Nominal
9. R-303 ALUMINUM	6.4 Zn, 2.5 Mg, 1.2 Cu, Balance Al	Nominal
10. 2020 ALUMINUM	Not Reported	
11. 2024 ALUMINUM	4.5 Cu, 1.5 Mg, .6 Mn, Balance Al	Nominal
12. 2024 ALCLAD ALUMINUM	4.5 Cu, 1.5 Mg, .6 Mn, Balance Al	Nominal
13. 2025 ALUMINUM	4.28 Cu, .36 Fe, .77 Mn, .76 Si, Balance Al	Actual
14. 2026 ALUMINUM	.5 Mg, .75 Si, .75 Mn, 4.5 Cu, Balance Al	Actual
15. 2219 ALUMINUM	.2 Si, .3 Fe, 6 Cu, .3 Mn, .02 Mg, .1 Zn, Balance Al	Actual
16. 2618 ALUMINUM	2.4 Cu, .25 Si, 1 Fe, 1.5 Mg, .08 Ti, .1 Ni, Balance Al	Actual
17. 5052 ALUMINUM	2.5 Mg, .25 Cr, Balance Al	Nominal
18. 5056 ALUMINUM	5.2 Mg, .1 Mn, .1 Cr, Balance Al	Nominal
19. 5083 ALUMINUM	.27 Fe, .15 Si, .06 Cu, .76 Mn, 4.48 Mg, .01 Zn, .09 Cr, .01 Ti, Balance Al	Actual

Alloy	Percent Composition	
20. 5086 ALUMINUM	4.0 Mg, .5 Mn, Balance Al	Nominal
21. 5154 ALUMINUM	3.5 Mg, .25 Cr, Balance Al	Nominal
22. 6061 ALUMINUM	1. Mg, .6 Si, .25 Cu, .25 Cr, Balance Al	Nominal
23. 5456 ALUMINUM	5. Mg, .7 Mn, .15 Cu, .15 Cr, Balance Al	Nominal
24. 7001 ALUMINUM	.11 Si, .12 Fe, 2.1 Cu, 3.03 Mg, 7.59 Zn, .2 Cr, .01 Ti, Balance Al	Actual
25. 7039 ALUMINUM	Not Reported	
26. 7075 ALUMINUM	5.5 Zn, 2.5 Mg, 1.5 Cu, .3 Cr, Balance Al	Nominal
27. 7075 ALCLAD ALUMINUM	5.5 Zn, 2.5 Mg, 1.5 Cu, .3 Cr, Balance Al	Nominal
28. 7076 ALUMINUM	.6 Cu, 7.6 Zn, 1.6 Mg, .6 Mn, .1 Ti, .5 Fe, .25 Si, Balance Al	Actual
29. 7106 ALUMINUM	.35 Si, .35 Fe, .1 Cu, .2 Mn, 2 Mg, 4 Zn, .1 Cr, Balance Al	Actual
30. 7079 ALUMINUM	4.3 Zn, 3.3 Mg, .6 Cu, .2 Mn, .2 Cr, Balance Al	Nominal
31. 7178 ALUMINUM	6.8 Zn, 2.7 Mg, 2.0 Cu, .3 Cr, Balance Al	Nominal
II. COBALT ALLOYS		
32. STELLITE-31	4.5 C, 24.8 Cr, .42 Mn, 10.4 Ni, .93 Si, 1.39 Fe, .01 P, .010 S, .03 Al, 7.26 W, Balance Co	Actual
33. S-816	.397 C, 1.12 Mn, .50 Si, 19.42 Cr, 20.62 Ni, 4.1 Mo, .018 S, .012 P, 2.86 Cb, 4.03 W, 2.99 Fe, 1.09 Ta, 42.9 Co	Actual
III. COPPER ALLOYS		
34. PURE COPPER	99.98 Cu	Nominal
35. 70-30 BRASS	70 Cu, 30 Zn	Nominal

Alloy		Percent Composition	
36.	Cu-73 Al BRONZE	92,7 Cu, 7.3 Al	Nominal
37.	5.6 Al BRONZE	94.4 Cu, 5.6 Al	Nominal
38.	Al-Ni BRONZE	81.75 Cu, .71 Mn, 2.86 Fe, 4.69 Ni, 9.90 Al	Actual
39.	PHOSPHOR BRONZE	94.05 Cu, .18 P, 4.2 Sn, .05 Pb	Actual
40.	MUNTZ METAL (BRASS)	60.3 Cu, 39.7 Zn	Actual
41.	Cu - 6.5 Al - 2.4 Fe	91.1 Cu, 6.5 Al, 2.4 Fe	Nominal
IV.	MAGNESIUM ALLOYS		
42.	2.5 Al MAGNESIUM	2.5 Al, 97.5 Mg	Nominal
43.	AZ31A MAGNESIUM	3 Al, 1 Zn, .2 Mn, Balance Mg	Nominal
44.	AZ31B MAGNESIUM	3 Al, 1 Zn, .2 Mn, Balance Mg	Nominal
45.	AZ61A MAGNESIUM	5.5 Al, 1 Zn, .2 Mn, Balance Mg	Nominal
46.	AZ80A-F MAGNESIUM	8.5 Al, .5 Zn, Balance Mg	Nominal
47.	AZ81 CAST MAGNESIUM	7.5 Al, .7 Zn, .15 Mn, Balance Mg	Nominal
48.	HM21 MAGNESIUM	2 Th, .5 Mn	Nominal
49.	ZK60A MAGNESIUM	5.6 Zn, .66 Zr, Balance Mg	Nominal
V.	NICKEL ALLOYS		
50.	"A" NICKEL	99.35 Ni + Co	Nominal
51.	FS-27 CERMET	34.3 Ti, 50 Ni, 6.2 Cr, 9.5 C	Actual
52.	HASTELLOY C	.05 C, .48 Mn, .64 Si, 56.6 Ni, 15.5 Cr, 16.2 Mo, 5.7 Fe, 3.8 W	Actual
53.	HASTELLOY-R235	.17 C, .017 S, 2.06 Al, 2.55 Ti, 5.31 Mo, 15.51 Cr, .27 Co, 9.95 Fe, .22 Si, .03 Mn, Balance Ni	Actual
54.	INCOLOY-901	12.41 Cr, 6.14 Mo, .18 Co, 2.67 Ti, .13 Al, 43.20 Ni, Balance Fe	Actual
55.	INCONEL	.02 C, .13 Mn, 6.81 Fe, .01 S, .17 Si, .06 Cu, 75.85 Ni, 15.54 Cr	Actual

	Alloy	Percent Composition	
56.	INCONEL-713C	11.9 Cr, .86 Fe, .49 Si, .13 Mn, .11 C, 5.0 Mo, 5.6 Al, .52 Ti, 2.1 Cb, Balance Ni	Actual
57.	INCONEL-X	.05 C, .57 Mn, 6.77 Fe, .29 Si .08 Cu, 72.85 Ni, 14.98 Cr, .72 Al, 2.54 Ti, 1.12 (Cb + Ta)	Actual
58.	INCONEL-718	.04 C, .20 Mn, .20 Si, 52.5 Ni, 19 Cr, 3 Mo, 18 Fe, .8 Ti, 5.2 Cb, .6 Al	Actual
59.	WASPALLOY	.1 Si, .1 Mn, 19.5 Cr, .55 Fe, 4.39 Mo, 13.5 Co, 2.87 Ti, 1.29 Al, Balance Ni	Actual
60.	INCONEL-751	.05 C, .73 Mn, .28 Si, 14.92 Cr, 2.5 Ti, 1.16 Al, 6.59 Fe, .03 Cu, 1.03 (Cb + Ta), Balance Ni	Actual
61.	INOR-8	Not Reported	
62.	MONEL	31.2 Cu, 66.9 Ni	Actual
63.	NICRO-TUNG	.1 C, .05 B, .05 Zr, 12 Cr, 10 Co, 8 W, 4 Al, 4 Ti, Balance Ni	Actual
64.	NIMONIC-95	.08 C, .36 Si, .06 Cu, .31 Fe, .08 Mn, 19.8 Cr, 2.98 Ti, 1.74 Al, 17.8 Co, Balance Ni	Actual
65.	RENE-41	19 Cr, 11 Co, 10 Mo, 3 Ti, 1.5 Al, Balance Ni	Nominal
66.	NIMONIC-80A	.08 C, .66 Si, .05 Cu, .3 Fe, .06 Mn, 19.7 Cr, 2.4 Ti, 1.18 Al, 1.0 Co, Balance Ni	Actual
67.	UDIMET-500	18.75 Cr, .57 Fe, 4.25 Mo, 17.61 Co, 3.09 Ti, 3.15 Al, Balance Ni, .1 Cu	Nominal
68.	UDIMET-650	.61 Al, 1.05 Ti, 2.90 Mo, 17.5 Cr, .1 Co, 17.2 Fe, 6.20 Ta, 2.75 W, .1 Si, .21 Mn, Balance Ni	Actual
69.	6 Mo WASPALLOY	.136 C, .56 Mn, .31 Si, 19.68 Cr, 6.32 Mo, 13.5 Co, 2.59 Ti, 1.04 Al, 2.5 Fe, Balance Ni	Actual

	Alloy	Percent Composition	
VI.	TITANIUM ALLOYS		
70.	Ti-A55	.051 C, .058 O_2, .01 Fe, Balance Ti	Actual
71.	Ti-75A	Not Reported	
72.	Ti-150A	2.6 Cr, 1.3 Fe, 0.2 O_2, Balance Ti	Nominal
73.	Ti-0.2 O_2	.25 O_2, 1.0 W, .061 C, Balance Ti	Actual
74.	Ti-0.2 C	.2 C, Balance Ti	Nominal
75.	Ti-N_2	.2 N_2, 1.0 W, Balance Ti	Actual
76.	Ti-.07 N_2-.2 O_2-.2 C	.26 C, .08 N_2, .1 Fe, .19 O_2, Balance Ti	Actual
77.	K-151A CERMET	58 Ti, 19 Ni, 7.5 Nb, .5 Ta, 15 C	Actual
78.	K-162B CERMET	52 Ti, 25 Ni, 5 Mo, 4.5 Nb, 3 Ta, 13.2 C	Actual
79.	K-183A CERMET	41 Ti, 32 Ni, 3 Mo, 2.5 Al, 7.5 Nb, 2.5 Cr, .5 Ta, 12 C	Actual
80.	Ti-4 Al-3 Mo-1 V	4 Al, 3 Mo, Balance Ti	Nominal
81.	Ti-4 Al-4 Mn	4 Al, 4 Mn, Balance Ti	Nominal
82.	Ti-5 Al-2.5 Sn	5 Al, 2.5 Sn, Balance Ti	Nominal
83.	Ti-5 Al-2.5 Sn-.07 N_2	.04 C, .07 N_2, .08 Fe, .12 O_2 5.04 Al, 2.5 Sn, Balance Ti	Nominal
84.	Ti-5 Al-2.5 Sn-.2 O_2	.05 C, .007 N_2, .1 Fe, .2 O_2, .5 Al, 2.5 Sn, Balance Ti	Nominal
85.	Ti-5 Al-2.5 Sn-.2 C	.2 C, .05 O_2, .007 N_2, .1 Fe, .5 Al, 2.5 Sn, Balance Ti	Nominal
86.	Ti-5 Al-2.5 Sn COMPLEX	Complex of the previous three	Nominal
87.	Ti-6 Al	.06 C, .035 N_2, .578 Al, Balance Ti	Actual
88.	Ti-6 Al-4 V	.02 C, .18 Fe, .011 N_2, 6 Al 4 V, Balance Ti	Nominal
89.	Ti-6 Al-4 V-.07 N_2	Not Reported	

	Alloy	Percent Composition	
90.	Ti-6 Al- 4V-.2 O_2	.07 C, .005 N_2, .12-.13 Fe, 67-82 H_2 ppm, 201 O_2, 6.03-6.37 Al, 4.18 V, Balance Ti	Actual
91.	Ti-6 Al-4 V-.2 C	.23-.24 C, .014-.016 N_2, .10-.13 Fe, 75-92 H_2 ppm, .113-.120 O_2, 6.10-6.35 Al, 4.12-4.24 V, Bal. Ti	Actual
92.	Ti-6 Al-4 V-.07 N_2-.2 O_2-.2 C	.19-.22 C, .052-.053 N_2, .09-.10 Fe, 62-63 H_2 ppm, .194-.201 O_2, 5.74-6.18 Al, 4.12-4.30 V, Bal. Ti	Actual
93.	Ti-7 Al-4 Mo	Not Reported	
94.	Ti-7 Al-3 Mo	.020 C, .03 Fe, 7.0 Al, 2.7 Mo, .004 H_2, Balance Ti	Actual
95.	Ti-8 Al-1 Mo-1 V	.023 C, .09 Fe, .013 N_2, 7.6 Al, 1.0 V, 1.1 Mo, .010-.014 H_2, Balance Ti	Actual
96.	Ti-3 Mn-.2 O_2	.02-.03 C, .016-.034 N_2, .80-.83 Fe, 36-39 H_2 ppm, .150-.175 O_2, 1.00-1.06 V, 3.0-3.2 Mn, .90-1.04 Cr, 1.15-1.20 Mo, Balance Ti	Actual
97.	Ti-3 Mn-.07 N_2	.03 C, .052-.053 N_2, .88-1.06 Fe, 43 H_2 ppm, .122-1.44 O_2, 1.00-1.06 V, 2.50-2.90 Mn, .96-1.08 Cr, 1.03 Mo, Balance Ti	Actual
98.	Ti-3 Mn-.2 C	.21-.22 C, .014-.017 N_2, 1.08-1.12 Fe, 96-108 H_2 ppm, .103-.148 O_2, 1.29-1.35 V, 3.00-3.05 Mn, .94-.98 Cr, 1.35-1.36 Mo, Balance Ti	Actual
99.	Ti-3 Mn COMPLEX	.02-.07 C, .011-.012 N_2, .86-.88 Fe, 48-64 H_2 ppm, .091-.082 O_2, 1.06-1.24 V, 3.08 Mn, .80-.96 Cr, 1.12-1.20 Mo, Balance Ti	Actual
100.	Ti-3 Mn-.07 N_2-.2 O_2-.2 C	.11-.15 C, .056-.057 N_2, .98-1.0 Fe, 54-58 H_2 ppm, .189-.216 O_2, 1.00-1.18 V, 2.5-2.6 Mn, .94-.96 Cr, 1.36-1.38 Mo, Balance Ti	Actual
101.	Ti-4 Mn	.14 C, .02 N_2, 4.20 Mn, Bal. Ti	Actual
102.	Ti-8 Mn	8 Mn, 92 Ti	Nominal

	Alloy	Percent Composition	
103.	Ti-30 Mo	.011-.016 C, .065-.069 N_2, 29.88-30.17 Mo, Balance Ti	
104.	Ti-13 V-11 Cr-3 Al	.029 C, .14 Fe, .028 N_2, 3.0 Al, 13.5 V, 11.2 Cr, .010 H_2, Bal. Ti	Actual
105.	Ti-16 V-2.5 Sn	16 V, 2.5 Sn, Balance Ti	Nominal
VII.	OTHER NON-FERROUS ALLOYS		
106.	BERILCO #25	Not Reported	
107.	PURE LEAD	99.995 Pb	Nominal
108.	0.5 Ti-MOLYBDENUM	0.46 Ti, 0.02 C, Balance Mo	Actual
109.	PURE TANTALUM	.08 Cb, .01 W, .01 Fe, Balance Ta	Actual
110.	10 W-TANTALUM	90 Ta, 10 W	Nominal
111.	PURE TUNGSTEN	Not Reported	

A-1.5 TABLES

A-1.5.1 Aluminum Alloys

S_u = 10 ksi
S_y = 9 ksi

1100 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Miscellaneous																
1		Milled #600 Gr.		80	1.0	Forged & Swaged	Weibull	b		3.470	3.460	3.460	3.460	3.460	3.460	3.460	3.460*
								θ		7.318	5.416	4.757	3.521	3.093	2.289	2.010	1.307
								X_o		3.077	2.284	2.006	1.484	1.304	.9653	.8479	.5512
	PLATE BENDING (Completely Reversed) Miscellaneous																
2	HT-1			80	V-Notch		Weibull	b	1.122*	1.076*	1.048*	1.037*	1.141	1.133	1.132	1.132	1.132*
								θ	4.734	3.816	3.282	3.076	2.657	2.491	2.144	2.010	1.623
								X_o	3.367	2.736	2.364	2.220	1.884	1.768	1.522	1.427	1.152
	AXIAL (Completely Reversed) Miscellaneous																
3				80	1.0		Weibull	b		5.295	4.969	5.290	5.290	5.290	4.969*	4.969*	5.290*
								θ		9.201	8.342	7.998	7.252	6.953	6.303	6.043	5.253
								X_o		6.554	6.068	5.699	5.167	4.954	4.585	4.396	3.743

HT-1: 1 hour at 320°C in Vacuum

S_u = 50 ksi
S_y = 40 ksi

5 Mg ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Stress Concentration

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
4				80	Ho-N		Weibull	b	2.476	2.559	2.522	2.507	2.506	2.506	2.506*	2.506*	2.506*
								θ	38.67	28.91	23.58	21.61	17.63	16.15	13.18	12.07	9.026
								X_o	26.01	19.24	15.78	14.48	11.81	10.82	8.834	8.093	6.049
5				80	1.0		Weibull	b	2.827	2.806	2.817	2.958	2.823	2.775	2.898	2.866	2.827*
								θ	44.70	30.01	22.72	20.16	15.25	13.53	10.24	9.088	6.102
								X_o	32.82	22.08	16.69	14.62	11.20	9.982	7.474	6.649	4.480

S_u = 30 ksi

355 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Surface Finish

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
6	T-6	As is		80	1.0	Cast	Weibull	b		2.699*	2.603	2.589	2.589	2.589	2.589*	2.589*	2.589*
								θ		28.12	21.09	18.63	13.98	12.35	9.272	8.193	5.431
								X_o		22.23	16.78	14.84	11.13	9.841	7.384	6.525	4.326
7	T-6	Polished		80	1.0	Cast	L.E.V.	β			.5511*	.6526	.9662	1.144	1.694*	2.005*	3.516*
								M			25.52	21.55	14.55	12.29	8.302	7.011	3.999

S_u = 40-60 ksi
S_y = 15-60 ksi

7.5 Zn - 2.5 Mg ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp°F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING Effect of Environment								
8	HT-2	Electropolished		80	1.0	Air Fatigue	S.E.V.	β M	.4048* 47.09	.5065* 37.64	.5923* 32.19	.6336* 30.09	.7410 25.73	.7927 24.05	.9270* 20.56	.9917* 19.22	1.240* 15.36
9	HT-2	Electropolished		80	1.0	Corrosion F.	L.E.V.	β M	.1403* 57.47	.2365* 34.09	.3406 23.67	.3986 20.22	.5742 14.04	.6719 12.00	.9679 8.331	1.132 7.119	1.909* 4.224
10	HT-3	Electropolished		80	1.0	Air Fatigue	L.E.V.	β M	.3660* 57.49	.4935* 42.64	.6081* 34.61	.6653* 31.63	.8198 25.67	.8969 23.46	1.105 19.04	1.209* 17.40	1.630* 12.91
11	HT-3	Electropolished		80	1.0	Corrosion F.	Weibull	b θ X_o	2.943* 59.67 41.73	2.866* 36.99 26.08	3.030* 26.49 18.35	2.959 22.94 16.01	3.015 16.43 11.40	2.972 14.22 9.919	2.891 10.18 7.162	2.874 8.819 6.213	2.874* 5.468 3.853
12	HT-4	Electropolished		80	1.0	Air Fatigue	Weibull	b θ X_o	3.271* 44.25 35.95	3.525* 33.36 26.72	3.404* 27.37 22.07	3.359* 25.13 20.32	3.268 20.62 16.76	3.233 18.94 15.42	3.188* 15.54 12.69	3.526* 14.28 11.43	3.526* 10.76 8.622
13	HT-4	Electropolished		80	1.0	Corrosion F.	Normal	σ μ	5.311* 51.946	3.504* 34.27	2.620* 25.63	2.312 22.61	1.729 16.91	1.525 14.92	1.141 11.16	1.006 9.847	.6643* 6.497

HT-2: Solution Heat Treated 450°C, W.Q.
HT-3: Solution Heat Treated 450°C, W.Q., Aged 0.1 day 150°C

S_u = 40-60 ksi
S_y = 15-60 ksi

7.5 Zn - 2.5 Mg ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Heat Treatment																
14	HT-2	Electropolished		80	1.0	Air Fatigue	S.E.V.	β	.4048*	.5065*	.5923*	.6336*	.7410	.7927	.9270*	.9917*	1.240*
								M	47.09	37.64	32.19	30.09	25.73	24.05	20.56	19.22	15.36
15	HT-3	Electropolished		80	1.0	Air Fatigue	L.E.V.	β	.3660*	.4935*	.6081*	.6653*	.8198	.8969	1.105	1.209*	1.630*
								M	57.49	42.64	34.61	31.63	25.67	23.46	19.04	17.40	12.91
16	HT-4	Electropolished		80	1.0	Air Fatigue	Weibull	b	3.271*	3.525*	3.404*	3.359*	3.268	3.233	3.188*	3.526*	3.526*
								θ	44.25	33.36	27.37	25.13	20.62	18.94	15.54	14.28	10.76
								X_o	35.95	26.72	22.07	20.32	16.76	15.42	12.69	11.43	8.622
17	HT-2	Electropolished		80	1.0	Corrosion Fatigue	L.E.V.	β	.1403*	.2365*	.3406	.3986	.5742	.6719	.9679	1.132	1.909*
								M	57.47	34.09	23.67	20.22	14.04	12.00	8.331	7.119	4.224
18	HT-3	Electropolished		80	1.0	Corrosion Fatigue	Weibull	b	2.943*	2.866*	3.030*	2.959	3.015	2.972	2.891	2.874	2.874*
								θ	59.67	36.99	26.49	22.94	16.43	14.22	10.18	8.819	5.468
								X_o	41.73	26.08	18.35	16.01	11.40	9.919	7.162	6.213	3.853
19	HT-4	Electropolished		80	1.0	Corrosion Fatigue	Normal	σ	5.311*	3.504*	2.620*	2.312	1.729	1.525	1.141	1.006	.6643*
								μ	51.946	34.27	25.63	22.61	16.91	14.92	11.16	9.847	6.497

HT-4: Solution Heat Treated, 450°C, W.Q., Aged, 10 days at 150°C

S_u = 37 ksi
S_y = 24 ksi

M - 257 ALUMINUM

Composition: See Page 166
(*) Excrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									AXIAL (Completely Reversed) Effect of Stress Concentration								
20	Sintered	Mechanical Polish 8 RMS	30	800	1.0		S.E.V.	β M	.5506* 21.66	.7611* 15.67	.9544* 12.49	1.052 11.33	1.319 9.040	1.454 8.201	1.824 6.539	2.010* 5.932	2.779* 4.291
21	Sintered	Mechanical Polish 8 RMS	30	800	3.0		S.E.V.	β M	.6087* 13.02	.9144* 8.670	1.215 6.523	1.373 5.771	1.825 4.342	2.063 3.841	2.742 2.890	3.100 2.557	4.657* 1.702
22	Sintered	Mechanical Polish 8 RMS	30	900	1.0		Weibull	b θ X_o	2.152* 13.33 10.90	2.152* 10.57 8.648	2.152 8.992 7.353	2.152 8.385 6.857	2.152 7.130 5.830	2.152 6.649 5.437	2.152 5.653 4.623	2.152 5.272 4.311	2.152* 4.180 3.418
23	Sintered	Mechanical Polish 8 RMS	30	900	3.0		L.E.V.	β M	.2987* 15.70	.5511* 8.510	.8456 5.546	1.016 4.612	1.560 3.006	1.876 2.499	2.878 1.629	3.461 1.354	6 387* .7343
									Effect of Test Temperature								
24	Sintered	M.P. - 8 RMS	30	800	1.0		S.E.V.	β M	.5506* 21.66	.7611* 15.67	.9544* 12.49	1.052 11.33	1.319 9.040	1.454 8.201	1.824 6.539	2.010* 5.932	2.779* 4.291
25	Sintered	M.P. - 8 RMS	30	900	1.0		Weibull	b θ X_o	2.152* 13.33 10.90	2.152* 10.57 8.648	2.152 8.992 7.353	2.152 8.385 6.857	2.152 7.130 5.330	2.152 6.649 5.437	2.152 5.653 4.623	2.152 5.272 4.311	2.152* 4.180 3.418

S_u = 37 ksi
S_y = 24 ksi

M-257 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Test Temperature																
26	Sintered	M.P. - 8 RMS	30	800	3.0		S.E.V.	β M	.6087* 13.02	.9144* 8.670	1.215 6.523	1.373 5.771	1.825 4.342	2.063 3.841	2.742 2.890	3.100 2.557	4.657* 1.702
27			30	900	3.0		L.E.V.	β M	.2987* 15.70	.5511* 8.510	.8456 5.546	1.016 4.612	1.560 3.006	1.876 2.499	2.878 1.629	3.461 1.354	6.387* .7343

S_u = 51 ksi
S_y = 39 ksi

M - 276 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
28	Sintered	M.P. - 8 RMS	30	800	1.0		Weibull	b θ X_o	3.390* 18.64 12.79	3.546* 15.28 10.32	3.544* 13.30 8.989	3.544* 12.52 8.466	3.544 10.90 7.366	3.544 10.26 6.938	3.544 8.932 6.036	3.544 8.413 5.685	3.544* 6.894 4.659
29			30	800	3.0		Weibull	b θ X_o	2.061* 12.24 8.568	2.061 8.768 6.133	2.061 6.941 4.855	2.061 6.276 4.390	2.061 4.968 3.475	2.061 4.492 3.142	2.061 3.556 2.487	2.061 3.215 2.249	2.061* 2.301 1.610

S_u = 51 ksi
S_y = 34 ksi

M-276 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	AXIAL (Completely Reversed)																
	Effect of Stress Concentration																
30	Sintered	M.P. - 8 RMS	30	900	1.0		L.E.V.	β	.7099*	.9066*	1.075*	1.157*	1.373	1.478	1.753*	1.887*	2.410*
								M	17.77	13.91	11.73	10.89	9.187	8.535	7.194	6.684	5.234
31	Sintered	M.P. - 8 RMS	30	900	3.0		Weibull	b	1.523*	1.523*	1.523*	1.523*	1.467	1.419	1.462	1.428	1.331*
								θ	12.28	8.707	6.845	6.171	4.847	4.368	3.435	3.095	2.192
								X_o	8.736	6.191	4.867	4.387	3.476	3.153	2.465	2.232	1.600
	Effect of Test Temperature																
32	Sintered	Mechanical Polish 8 RMS	30	800	1.0		Weibull	b	3.390*	3.546*	3.544*	3.544*	3.544	3.544	3.544	3.544	3.544*
								θ	18.64	15.28	13.30	12.52	10.90	10.26	8.932	8.413	6.894
								X_o	12.79	10.32	8.989	8.466	7.366	6.938	6.036	5.685	4.659
33	Sintered	Mechanical Polish 8 RMS	30	900	1.0		L.E.V.	β	.7099*	.9066*	1.075*	1.157*	1.373	1.478	1.753*	1.887*	2.410*
								M	17.77	13.91	11.73	10.89	9.187	8.535	7.194	6.684	5.234
34	Sintered	Mechanical Polish 8 RMS	30	800	3.0		Weibull	b	2.061*	2.061	2.061	2.061	2.061	2.061	2.061	2.061	2.061*
								θ	12.24	8.768	6.941	6.276	4.968	4.492	3.556	3.215	2.301
								X_o	8.568	6.133	4.855	4.390	3.475	3.142	2.487	2.249	1.610
35	Sintered	Mechanical Polish 8 RMS	30	900	3.0		Weibull	b	1.523*	1.523*	1.523*	1.523*	1.467	1.419	1.462	1.428	1.331*
								θ	12.28	8.707	6.845	6.171	4.847	4.368	3.435	3.095	2.192
								X_o	8.736	6.191	4.867	4.387	3.476	3.153	2.465	2.232	1.600

S_u = 68-78 ksi
S_y = 60-71 ksi

2014 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING Miscellaneous								
36	T-6 Wrought			80	1.0		Weibull	b θ X_o	1.921* 75.93 68.38	1.781 63.92 57.85	1.682 56.68 51.46	1.636 53.81 48.94	1.770 47.75 43.23	1.522 45.31 41.34	1.642 40.20 36.55	1.689 38.18 34.66	1.824* 32.17 29.07
37	T-6 H-Roll	M.P.		80	1.0		S.E.V.	β M		.1986* 67.72	.2648 50.79	.2997 44.88	.3996 33.66	.4523 29.74	.6030 22.30	.6825* 19.70	1.030* 13.06
									PLATE BENDING (Completely Reversed) Effect of Heat Treatment								
38	T-4		1000	80	1.0		L.E.V.	β M		.2193 59.51	.2808 46.48	.3123 41.79	.3999 32.64	.4448 29.35	.5695 22.92	.6334 20.61	.9020 14.47
39	T-6		1000	80	1.0		Weibull	b θ X_o		1.090* 58.99 47.46	1.422* 47.21 36.24	1.422 42.70 32.78	.8265 33.22 27.43	.7622 30.02 24.87	1.054 23.95 19.36	1.097 21.70 17.44	1.201* 15.60 12.37

S_u = 68-78 ksi
S_y = 60-71 ksi

2014 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS		LIFE IN CYCLES								
									PLATE BENDING (Completely Reversed) — Effect of Frequency								
40	T-4		1000	80	1.0		L.E.V.	β		.2193	.2808	.3123	.3999	.4448	.5695	.6334	.9020
								M		59.51	46.48	41.79	32.64	29.35	22.92	20.61	14.47
41	T-4		300	80	1.0		Weibull	b	1.828*	.9438	1.113	1.211	1.010	1.088	1.180	1.156	1.180*
								θ	69.34	50.05	40.13	36.51	29.20	26.56	21.30	19.35	14.10
								X_o	56.53	43.39	34.56	31.26	25.27	22.90	18.27	16.63	12.09
42	T-6		1000	80	1.0		Weibull	b		1.090*	1.422*	1.422	.8265	.7622	1.054	1.097	1.201*
								θ		58.99	47.21	42.70	33.22	30.02	23.95	21.70	15.60
								X_o		47.46	36.24	32.78	27.43	24.87	19.36	17.44	12.37
43	T-6		100	80	1.0		Weibull	b	1.835*	1.991*	1.991	1.991	1.827	1.991	1.991	1.991	1.991*
								θ	57.47	41.22	32.66	29.54	23.39	21.17	16.77	15.17	10.88
								X_o	49.11	34.91	27.66	25.02	19.99	17.93	14.21	12.85	9.214
									Effect of Stress Concentration								
44	T-6			80	1.0	Longitudinal	Weibull	b		1.392*	1.380	1.300	1.169	1.355	1.204	1.366	1.440
								θ		66.86	53.56	48.65	38.93	35.45	28.36	25.82	18.81
								X_o		61.26	49.10	44.77	36.03	32.54	26.21	23.68	17.20
45	T-6			80	Notched	Longitudinal	Normal	σ	6.375	4.584	3.639	3.295	2.616	2.369	1.881	1.703	1.224
								μ	45.55	32.74	26.00	23.54	18.69	16.92	13.44	12.17	8.750

S_u = 68-78 ksi
S_y = 60-71 ksi

2014 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
46	T-6	Ground - 10 RMS		80	1.0	Long Transverse	Weibull	b	4.211*	4.113	4.057	4.035	3.992	3.975	3.941	3.927	3.775*
								θ	63.80	49.93	42.07	39.08	32.93	30.59	25.77	23.94	18.73
								X_o	33.99	27.04	22.99	21.43	18.19	16.94	14.35	13.36	10.71
47	T-6	Ground - 10 RMS		80	Notched	Long Transverse	Weibull	b	5.473	5.619	6.015	5.779	5.781	5.719	5.595	5.927	5.473
								θ	42.25	30.75	24.62	22.38	17.92	16.28	13.04	11.85	8.626
								X_o	31.52	22.76	17.83	16.42	13.14	11.99	9.667	8.627	6.435
48	T-6	Ground - 10 RMS	60	80	1.0	Cold Drawn	Weibull	b	1.101*	1.129	1.424	1.681	1.521	1.529	1.400*	1.348*	1.222*
								θ	63.97	48.68	40.27	37.14	30.66	28.24	23.31	21.46	16.31
								X_o	59.27	45.06	36.86	33.61	27.94	25.72	21.35	19.70	15.05
49	T-6	Ground - 10 RMS	60	80	1.6	Cold Drawn	Normal	σ	1.990*	1.559*	1.315	1.222	1.030	.9578	.8078*	.7506*	.5883*
								μ	49.76	38.99	32.88	30.56	25.77	23.95	20.19	18.77	14.71
50	T-6	Ground - 10 RMS	60	80	2.4	Cold Drawn	S.E.V.	β	.5842*	.7635*	.9206	.9979	1.203	1.304	1.572	1.704	2.227*
								M	38.32	29.32	24.31	22.43	18.60	17.16	14.23	13.13	10.04
51	T-6	Ground - 10 RMS	60	80	3.4	Cold Drawn	Weibull	b	1.796*	1.796*	1.796	1.796	1.796	1.796	1.796	1.796	1.796*
								θ	37.80	26.51	20.69	18.59	14.51	13.04	10.18	9.151	6.419
								X_o	27.95	19.60	15.30	13.75	10.73	9.647	7.529	6.767	4.746

S_u = 68-78 ksi
S_y = 60-71 ksi

2014 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
									PLATE BENDING (Completely Reversed) — Effect of Stress Concentration								
52	T-6	Mechanical Polish	60	80	1.0	Hot Rolled	L.E.V.	β	.1045*	.1532	.2229	.2549	.3480	.3980	.5435*	.6216*	.9706*
								M	65.37	41.86	30.66	26.81	19.63	17.17	12.57	10.99	7.041
53	T-6	Mechanical Polish	60	80	3.5	Hot Rolled	Weibull	b	3.251	3.248	3.132	3.092	3.088	3.088*	3.088*	3.088*	3.088*
								θ	35.80	22.14	15.82	13.68	9.782	8.464	6.049	5.234	3.235
								X_o	26.80	16.58	11.95	10.37	7.416	6.417	4.586	3.968	2.454
54	T-6	Mechanical Polish	60	80	8.0	Hot Rolled	S.E.V.	β	.2029*	.3450	.5000	.5866	.8501	.9974*	1.445*	1.695*	2.883*
								M	34.26	20.15	13.90	11.85	8.180	6.972	4.811	4.101	2.412
									Effect of Grain Direction								
55	T-6			80	1.0	Longi-tudinal	Weibull	b	1.172*	1.392*	1.380	1.300	1.169	1.355	1.204	1.366	1.440
								θ	91.63	66.86	53.56	48.65	38.93	35.45	28.36	25.82	18.81
								X_o	84.78	61.26	49.10	44.77	36.03	32.54	26.21	23.68	17.20
56	T-6			80	1.0	Long-Trans.	Weibull	b	4.211*	4.113	4.057	4.035	3.992	3.975	3.941	3.927	3.775*
								θ	63.80	49.93	42.07	39.08	32.93	30.59	25.77	23.94	18.73
								X_o	33.99	27.04	22.99	21.43	18.19	16.94	14.35	13.36	10.71

S_u = 68-73 ksi
S_y = 60-71 ksi

2014 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	PLATE BENDING (Completely Reversed) — Effect of Grain Size																
57	T-6			80	Notched	Longi-tudinal	Normal	σ μ	6.375 45.55	4.584 32.74	3.639 26.00	3.295 23.54	2.616 18.69	2.369 16.92	1.881 13.44	1.703 12.17	1.224 8.750
58	T-6			80	Notched	Long-Trans.	Weibull	b θ X_o	5.473 42.25 31.52	5.619 30.75 22.76	6.015 24.62 17.83	5.779 22.38 16.42	5.781 17.92 13.14	5.719 16.28 11.99	5.595 13.04 9.667	5.927 11.85 8.627	5.473 8.626 6.435
	Effect of Manufacturing Processes																
59	T-6	Ground 10 RMS		80	1.0	As is	Weibull	b θ X_o	.6891 62.08 58.30	.7568 47.48 44.41	.6891 39.21 36.82	.6891 36.15 33.95	.6891* 29.92 28.10	.6891* 27.58 25.90	.6135* 22.80 21.46	.6891* 21.05 19.76	1.314* 16.38 14.60
60	T-6	Ground 10 RMS	60	80	1.0	Extruded	Weibull	b θ X_o	1.269* 63.27 57.39	1.385* 50.75 45.75	.9769* 43.32 39.86	.8802* 40.50 37.40	1.084 34.75 31.82	1.094 32.52 29.76	.9773 27.83 25.60	.9271 26.02 23.99	1.250* 20.91 18.99
61	T-6	Ground 10 RMS	60	80	1.0	Cold Drawn	Weibull	b θ X_o	1.101* 63.97 59.27	1.129 48.68 45.06	1.424 40.27 36.86	1.681 37.14 33.61	1.521 30.66 27.94	1.529 28.24 25.72	1.400* 23.31 21.35	1.348* 21.46 19.70	1.222* 16.31 15.05

S_u = 64—67 ksi

2014 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									PLATE BENDING (Completely Reversed) Effect of Manufacturing Processes								
62	T-6	M.P.	60	80	1.0	Forged	Weibull	b	2.105*	2.108*	2.105	2.105	2.105	2.133	2.105	2.105	2.105*
								θ	50.51	42.62	37.86	35.97	31.95	30.36	26.96	25.62	21.62
								X_o	37.11	31.31	27.82	26.43	23.47	22.25	19.81	18.82	15.89
63	T-6	M.P.	60	80	1.0	Hot Rolled	L.E.V.	β	.1045*	.1632	.2229	.2549	.3480	.3980	.5435*	.6216*	.9706*
								M	65.37	41.86	30.66	26.81	19.63	17.17	12.57	10.99	7.041

S_u = 57 ksi
S_y = 41 ksi

2014 ALCLAD ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Heat Treatment

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
64	T-4		1000	80	1.0		Weibull	b		2.226*	2.226*	2.226*	2.287	2.218	2.289	2.241	2.318*
								θ		48.44	37.75	33.90	26.43	23.73	18.49	16.61	11.63
								X_o		37.04	28.86	25.92	20.09	18.16	14.06	12.68	8.816
65	T-6		1000	80	1.0		Weibull	b		1.758*	1.828*	1.738*	1.791	1.724	1.842	1.800	1.727
								θ		53.54	39.76	34.96	25.96	22.83	16.96	14.91	9.739
								X_o		43.19	31.90	28.25	20.89	18.46	13.59	11.99	7.875

S_u = 64—67 ksi

2014 ALCLAD ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	PLATE BENDING (Completely Reversed) Effect of Frequency																
66	T-4		1000	80	1.0		Weibull	b θ X_o		2.226* 48.44 37.04	2.226* 37.75 28.86	2.226* 33.90 25.92	2.287 26.43 20.09	2.218 23.73 18.16	2.289 18.49 14.06	2.241 16.61 12.68	2.318* 11.63 8.816
67	T-4		32	80	1.0		Normal	σ μ	4.827* 43.14	3.391* 30.31	2.650* 23.68	2.383 21.29	1.862 16.64	1.674 14.96	1.308 11.69	1.176 10.51	.8266* 7.388
68	T-6		1000	80	1.0		Weibull	b θ X_o		1.758* 53.54 43.19	1.828* 39.76 31.90	1.738* 34.96 28.25	1.791 25.96 20.89	1.724 22.83 18.46	1.842 16.96 13.59	1.800 14.91 11.99	1.727 9.739 7.875
69	T-6		10	80	1.0		Weibull	b θ X_o	1.962* 44.15 34.45	1.962* 27.26 21.27	2.052 19.47 15.06	1.956 16.83 13.14	1.987 12.02 9.358	2.134 10.40 7.990	2.026 7.424 5.759	1.990 6.421 4.997	1.962* 3.964 3.093
	Miscellaneous																
70	T-6			80	Ho-N		Weibull	b θ X_o	1.891 48.36 27.64	1.888 30.74 17.58	1.881 22.40 12.83	1.848 19.53 11.27	1.876 14.24 8.166	1.855 12.42 7.156	1.906* 9.055 5.158	1.893* 7.900 4.514	1.891* 5.022 2.870

S_u = 82 ksi
S_y = 77 ksi

R-303 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
									ROTARY BEAM BENDING — Miscellaneous								
71		LTB	177	80	1.0	Cast	S.E.V.	β M		.1743* 66.37	.2219* 52.12	.2463* 46.97	.3136 36.89	.3480 33.24	.4431 26.10	.4918 23.52	.6949* 16.65
									PLATE BENDING (Completely Reversed) — Miscellaneous								
72		Ground	29.2	80	1.0	Extrusion	Weibull	b θ X_o	3.749* 60.25 50.37	3.493* 48.13 40.68	4.143* 41.15 33.80	4.061 38.46 31.71	3.891 32.87 27.30	4.255 30.72 25.11	4.334 26.26 21.39	4.067 24.54 20.23	4.346* 19.61 15.96

S_u = 83 ksi
S_y = 79 ksi

2020 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
73	T-6	M.P.		80	1.0	Hot Rolled	S.E.V.	β M	.1540* 59.25	.2221 41.07	.2870 31.79	.3205 28.47	.4141 22.03	.4624 19.73	.5974* 15.27	.6671* 13.67	.9624* 9.481

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Specimen Configuration

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
74				80	1.0	SP-1	S.E.V.	β	.4984*	.6045	.6918*	.7331*	.8390*	.8891*	1.017*	1.078*	1.307*
								M	59.08	48.72	42.57	40.17	35.10	33.12	28.94	27.31	22.52
75				80	1.0	SP-3	S.E.V.	β	.4407*	.7218*	1.018	1.182*	1.668*	1.935*	2.732*	3.170*	5.191*
								M	45.20	27.60	19.55	16.85	11.94	10.29	7.291	6.285	3.838
76	T-3	Milled Edges and Electropolished	25	80	2.0	SP-5	Weibull	b	.8607*	1.273	1.245	.9326	1.164*	1.122*	.8667*	.7379*	1.231*
								θ	41.82	28.61	21.89	19.46	14.92	13.29	10.15	9.045	6.191
								X_o	39.36	26.51	20.31	18.27	13.89	12.39	9.556	8.537	5.746
77	T-3		25	80	2.0	SP-4	Weibull	b	1.623*	1.907	1.789	1.807	1.872	1.785*	1.908*	1.852*	1.722*
								θ	43.97	28.74	21.33	18.76	13.93	12.25	9.100	8.003	5.224
								X_o	37.15	23.86	17.84	15.67	11.59	10.25	7.555	6.668	4.388
78	T-3		25	80	2.0	SP-7	S.E.V.	β	.5159*	.7277	.9254	1.026	1.305	1.447	1.840	2.041*	2.878*
								M	41.93	29.73	23.38	21.08	16.58	14.95	11.75	10.60	7.516
79	T-3			80	4.0	SP-2	Weibull	b	2.474*	2.474	2.416	2.360	2.398	2.360	2.431	2.405	2.480*
								θ	27.67	19.03	14.64	13.08	10.06	8.994	6.924	6.185	4.253
								X_o	18.08	12.43	9.647	8.681	6.648	5.969	4.551	4.080	2.777

SP-1 - Sheet- .125 in. or less, unnotched
SP-2 - Sheet - .125 in. or less, Symmetrical Edge Notch, Flank Angle (0) Degree
SP-3 - Sheet - .125 in. hick or less. hole notch

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									AXIAL (Completely Reversed) Effect of Specimen Configuration								
80	T-3	Milled Edges Electropolished	25	80	4.0	SP-4	Weibull	b	2.735*	2.681	2.681	2.681	2.681	2.681	2.681	2.681*	2.681*
								θ	25.17	17.59	13.69	12.29	9.572	8.593	6.690	6.006	4.197
								X_o	17.97	12.63	9.835	8.830	6.874	6.171	4.804	4.313	3.014
81	T-3	Milled Edges Electropolished	25	80	4.0	SP-7	Normal	σ	2.257*	1.502	1.130	1.000	.7526	.6659	.5010*	.4433*	.2951*
								μ	31.46	20.94	15.76	13.94	10.49	9.282	6.984	6.179	4.113
									Effect of Frequency								
82	T-3	Electropolished	24	80	2.9	SP-3	Weibull	b	1.767*	1.784*	1.898	1.844	1.767	1.767	1.871	1.841	1.767*
								θ	33.12	24.77	20.23	18.53	15.12	13.85	11.31	10.36	7.751
								X_o	27.35	20.43	16.55	15.22	12.49	11.44	9.276	8.517	6.402
83	T-3	Electropolished	37	80	2.9	SP-3	Weibull	b	6.692*	6.604*	6.352	6.119	5.703	5.566	5.386	5.340	5.213*
								θ	34.92	26.11	21.31	19.52	15.93	14.60	11.91	10.91	8.164
								X_o	19.54	14.74	12.33	11.54	9.790	9.079	7.527	6.924	5.233
84	T-3	Electropolished	24	80	2.8	SP-3	Weibull	b	1.616*	1.459	1.540	1.609	1.592	1.527	1.706	1.660	1.531*
								θ	31.61	23.49	19.11	17.48	14.21	13.00	10.57	9.674	7.190
								X_o	26.67	20.00	16.19	14.75	12.01	11.02	8.874	8.139	6.097
85	T-3	Electropolished	37	80	2.8	SP-3	Normal	σ	4.820*	3.707	3.086	2.851	2.373	2.193	1.825	1.687	1.297*
								μ	31.88	24.52	20.41	18.86	15.70	14.50	12.07	11.15	8.583

SP-4 - Sheet - .125 in. thick or less, Symmetrical Edge Notch, Flank Angle 0 Degree Grain direction parallel to lengthwise axis

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 165
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Frequency

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
86	T-3	Electropolished	6	80	2.6	SP-3	Normal	σ μ	3.141* 30.35	2.318 22.40	1.875 18.12	1.711 16.53	1.384 13.37	1.263 12.20	1.021 9.874	.9326 9.012	.6885* 6.652
87	T-3	Electropolished	37	80	2.6	SP-3	Weibull	b θ X_o	1.781* 35.07 27.76	1.862 26.37 20.74	1.775 21.59 17.10	1.977 19.83 15.45	1.916 16.24 12.72	1.893 14.90 11.69	1.863 12.20 9.604	1.863 11.20 8.813	1.863 8.423 6.625
88	T-3	Electropolished	6	80	2.4	SP-3	Weibull	b θ X_o	3.549* 30.77 20.08	3.560 23.42 15.27	3.463 19.35 12.75	3.426 17.82 11.79	3.539 14.73 9.630	3.511 13.57 8.897	3.455 11.21 7.396	3.433 10.33 6.828	3.374* 7.863 5.230
89	T-3	Electropolished	24-30	80	2.4	SP-3	Weibull	b θ X_o	1.984* 36.25 30.29	1.767 27.76 23.48	1.980 23.07 19.28	1.936 21.29 17.84	1.844 17.67 14.88	1.808 16.31 13.76	1.734 13.54 11.47	1.719 12.49 10.59	1.719* 9.579 8.123
90	T-3	Electropolished	6	80	2.2	SP-3	Weibull	b θ X_o	3.591* 31.83 21.87	3.640* 24.55 16.78	3.547 20.46 14.12	3.512 18.92 13.10	3.441 15.78 10.99	3.628 14.59 9.994	3.574 12.17 8.377	3.553 11.25 7.761	3.512* 8.680 6.007
91	T-3	Electropolished	24-30	80	2.2	SP-3	Normal	σ μ	3.561* 27.98	2.924* 22.97	2.547 20.01	2.401 18.86	2.092 16.43	1.971 15.49	1.717 13.49	1.618 12.71	1.329* 10.44

SP-5 Sheet-.125 in. thick or less, Hole Notch, grain direction parallel to lengthwise axis
SP-6 Sheet-.125 in. thick or less, Unnotched, Constant stress test length

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
									AXIAL (Completely Reversed) Effect of Stress Concentration								
92	T-3	Electropolished	24	80	2.9	SP-3	Weibull	b	1.767*	1.784*	1.898	1.844	1.767	1.767	1.871	1.841	1.767*
								θ	33.12	24.77	20.23	18.53	15.12	13.85	11.31	10.36	7.751
								X_o	27.35	20.43	16.55	15.22	12.49	11.44	9.276	8.517	6.402
93	T-3	Electropolished	24	80	2.8	SP-3	Weibull	b	1.616*	1.459	1.540	1.609	1.592	1.527	1.706	1.660	1.531*
								θ	31.51	23.49	19.11	17.48	14.21	13.00	10.57	9.674	7.190
								X_o	26.67	20.00	16.19	14.75	12.01	11.02	8.874	8.139	6.097
94	T-3	Electropolished	6	80	2.6	SP-3	Normal	σ	3.141*	2.318	1.875	1.711	1.384	1.263	1.021	.9326	.6885*
								μ	30.35	22.40	18.12	16.53	13.37	12.20	9.874	9.012	6.652
95	T-3	Electropolished	6	80	2.4	SP-3	Weibull	b	3.549*	3.560	3.463	3.426	3.539	3.511	3.455	3.433	3.374*
								θ	30.77	23.42	19.35	17.82	14.73	13.57	11.21	10.33	7.863
								X_o	20.08	15.27	12.75	11.79	9.630	8.897	7.396	6.828	5.230
96	T-3	Electropolished	6	80	2.2	SP-3	Weibull	b	3.591*	3.640*	3.547	3.512	3.441	3.628	3.574	3.553	3.512*
								θ	31.83	24.55	20.46	18.92	15.78	14.59	12.17	11.25	8.680
								X_o	21.87	16.78	14.12	13.10	10.99	9.994	8.377	7.761	6.007
97	T-3	Electropolished	37	80	2.9	SP-3	Weibull	b	6.692*	6.604*	6.352	6.119	5.703	5.566	5.386	5.340	5.213*
								θ	34.92	26.11	21.31	19.52	15.93	14.60	11.91	10.91	8.164
								X_o	19.54	14.74	12.33	11.54	9.790	9.079	7.527	6.924	5.233

SP-7: Sheet - .125 in. thick or less, Fillet notch, grain direction parallel to lengthwise axis
SP-8: Plate - over .125 in. thick, Unnotched

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS: DIST.	Param.	LIFE IN CYCLES: $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
98	T-3	Electropolished	37	80	2.8	SP-3	Normal	σ μ	4.820* 31.88	3.707 24.52	3.086 20.41	2.851 18.86	2.373 15.70	2.193 14.50	1.825 12.07	1.687 11.15	1.297* 8.583
99	T-3	Electropolished	37	80	2.6	SP-3	Weibull	b θ X_o	1.781* 35.07 27.76	1.862 26.37 20.74	1.775 21.59 17.10	1.977 19.83 15.45	1.916 16.24 12.72	1.893 14.90 11.69	1.863 12.20 9.604	1.863 11.20 8.813	1.863* 8.423 6.625
100	T-3	Electropolished	24-30	80	2.4	SP-3	Weibull	b θ X_o	1.984* 36.25 30.29	1.767 27.76 23.48	1.980 23.07 19.28	1.936 21.29 17.84	1.844 17.67 14.88	1.808 16.31 13.76	1.734 13.54 11.47	1.719 12.49 10.59	1.719* 9.579 8.123
101	T-3	Electropolished	24-30	80	2.2	SP-3	Normal	σ μ	3.561* 27.98	2.924* 22.97	2.547 20.01	2.401 18.86	2.092 16.43	1.971 15.49	1.717 13.49	1.618 12.71	1.329* 10.44
102	T-3	Milled Edges Electropolish	25	80	1.5	SP-4	S.F.V.	β M	.3392* 49.18	.4580 36.43	.5649 29.53	.6183 26.98	.7627 21.87	.8348 19.98	1.029* 16.20	1.127* 14.80	1.521* 10.96
103	T-3	Milled Edges Electropolish	25	80	2.0	SP-4	Weibull	b θ X_o	1.623* 43.97 37.15	1.907 28.74 23.86	1.789 21.33 17.84	1.807 18.76 15.67	1.872 13.93 11.59	1.785* 12.25 10.25	1.908* 9.100 7.555	1.852* 8.003 6.668	1.722* 5.224 4.388

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
104	T-3	Milled Edges Electropolished	25	80	4.0	SP-4	Weibull	b	2.735*	2.681	2.681	2.681	2.681	2.681	2.681	2.681*	2.681*
								θ	25.17	17.59	13.69	12.29	9.572	8.593	6.690	6.006	4.197
								X_o	17.97	12.63	9.835	8.830	6.874	6.171	4.804	4.313	3.014
105	T-3		25	80	5.0	SP-4	Weibull	b	4.602*	4.413	4.322	4.291	4.237	4.237	4.237*	4.214*	3.986*
								θ	28.20	18.10	13.27	11.61	8.521	7.456	5.468	4.785	3.071
								X_o	14.55	9.613	7.143	6.279	4.641	4.061	2.978	2.614	1.732
106				80	1.0		Weibull	b	1.627*	1.921	1.974	1.921	1.808	1.763*	1.667*	1.661*	1.661*
								θ	66.99	49.89	40.60	37.14	30.20	27.63	22.47	20.56	15.30
								X_o	57.28	42.10	34.16	31.33	25.63	23.49	19.19	17.56	13.07
107				80	Ho-N		Weibull	b	3.491	3.306	3.206	3.168	3.158	3.158	3.158	3.158*	3.158*
								θ	40.40	29.74	24.01	21.90	17.68	16.12	13.02	11.87	8.743
								X_o	32.63	24.24	16.66	17.96	14.51	13.23	10.68	9.747	7.177
108	T-3			80	4.0		S.E.V.	β	.7311*	1.001	1.248	1.372	1.710	1.880	2.343	2.576	3.530*
								M	25.13	18.34	14.72	13.38	10.74	9.771	7.841	7.131	5.205
109	T-3			80	1.0		Weibull	b	3.514*	3.701	3.536	3.477	3.637	3.596	3.516*	3.515*	3.515*
								θ	75.56	52.58	40.79	36.57	28.38	25.44	19.74	17.70	12.31
								X_o	56.75	38.98	30.59	27.53	21.13	19.00	14.82	13.29	9.249

S_u = 61-81 ksi
S_y = 45=61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									AXIAL (Completely Reversed) Effect of Notch Radius								
110	T-3			80	4.0	N. Rad. .004 in.	Weibull	b	2.559*	2.548	2.546	2.476	2.502	2.454	2.524	2.491	2.568*
								θ	45.82	31.22	23.88	21.27	16.27	14.49	11.09	9.881	6.735
								X_o	31.74	21.66	16.57	14.89	11.35	10.17	7.717	6.902	4.661
111	T-3			80	4.0	N. Rad. .07 in.	S.E.V.	β	.9643*	1.345	1.697	1.876	2.367	2.616	3.301	3.649*	5.090*
								M	24.52	17.58	13.93	12.60	9.989	9.037	7.162	6.479	4.645
									PLATE BENDING (Completely Reversed) Effect of Stress Concentration								
112	T-4	Ground	30	80	7.4	SP-3	Normal	σ	4.146*	2.250	1.468	1.221	.7972	.6633*	.4327*	.3600*	.1954*
								μ	54.71	29.70	19.37	16.12	10.52	8.753	5.711	4.751	2.579
113	T-4	Ground	30	80	7.9	SP-3	Weibull	b	1.043*	1.083	1.368	1.407	1.466*	1.476*	1.476*	1.476*	1.476*
								θ	72.31	35.11	21.55	17.36	10.50	8.450	5.092	4.094	1.983
								X_o	59.60	28.75	16.52	13.18	7.836	6.286	3.788	3.045	1.475

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(SHEET OR PLATES)

Composition: See Page 166
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
114	T-3	Ground Edges	30	80	1.0	SP-6	S.E.V.	β M		.2428* 59.04	.3265 43.91	.3709 38.65	.4987 28.75	.5665 25.31	.7616* 18.82	.8652* 16.57	1.321* 10.85
115	T-4	M.P.	30	80	1.0	SP-8	Normal	σ μ		3.123* 57.64	2.376* 43.85	2.112* 38.98	1.607 2[illegible]66	1.428 26.36	1.087 20.06	.9663 17.83	.6536* 12.06

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM
(BARS)

Composition: See Page 166
(*) Extrapolated Values

ROTARY BEAM BENDING
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
116	T-4	M.P.	25	80	1.0	Cold Rolled	Weibull	b θ X_o	3.332* 63.25 46.01	3.277* 50.49 36.90	3.262 43.14 31.56	3.404 40.32 29.15	3.279 34.44 25.16	3.242 32.18 23.58	3.398 27.50 19.89	3.368 25.69 18.63	3.283* 20.51 14.98
117	T-4	Ground	25	80	3.9	Cold Rolled	Normal	σ μ	4.684* 25.46	3.815 20.74	3.306 17.97	3.108 16.89	2.693 14.63	2.532 13.76	2.194 11.92	2.062* 11.21	1.680* 9.133

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(BARS)

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
118	T-4	Ground - 10 RMS	60	80	1.0	Cold Drawn	Normal	σ μ	3.818* 62.30	3.020 49.28	2.564 41.84	2.389 38.99	2.028 33.10	1.890 30.84	1.604 26.18	1.495* 24.40	1.183* 19.30
119	T-4	Ground - 10 RMS	60	80	1.6	Cold Drawn	Weibull	b θ X_o	1.729* 49.61 43.98	1.303* 38.46 34.68	1.434 32.24 28.95	1.372 29.87 26.88	1.717 25.07 22.24	1.680 23.23 20.64	1.609* 19.46 17.35	1.609* 18.03 16.07	1.609* 14.00 12.48
120	T-4	Ground - 10 RMS	60	80	2.4	Cold Drawn	Weibull	b θ X_o	1.850* 42.70 34.71	1.850 31.77 25.83	1.851 25.84 21.01	1.851 23.64 19.22	1.851 19.23 15.63	1.851 17.59 14.30	1.851 14.31 11.63	1.851* 13.09 10.64	1.851* 9.743 7.921
121	T-4	Ground - 10 RMS	60	80	3.4	Cold Drawn	Weibull	b θ X_o	.9193* 48.66 43.36	.7968 30.99 27.75	.9826 22.67 20.14	1.182 19.85 17.43	.7652 14.43 12.93	1.083 12.64 11.17	.8076* 9.205 8.240	1.148* 8.070 7.101	.9826* 5.135 4.562
122	T-3		20	80	1.0		S.E.V.	β M	.1486* 76.31	.2151 52.70	.2787 40.69	.3115 36.40	.4035 28.11	.4510 25.14	.5841 19.41	.6530 17.37	.9453* 11.99
123	T-3		20	80	2.0		S.E.V.	β M	.2787 41.32	.4035 28.54	.5227 22.04	.5642 19.71	.7567 15.22	.8458 13.62	1.095* 10.51	1.224* 9.408	1.772* 6.498

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(BARS)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) — Effect of Stress Concentration (Continued)																
124	T-3		20	80	4.0		Weibull	b	5.948	5.670	5.547	5.503	5.257	5.159	5.005	4.950*	4.805*
								θ	26.51	18.23	14.03	12.53	9.651	8.622	6.637	5.929	4.077
								X_o	14.17	10.06	7.854	7.051	5.574	5.031	3.935	3.535	2.467

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM
(EXTRUSIONS)

Composition: See Page 166
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Manufacturing Processes

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
125	T-4	Longitudinal		80	Notched	As is	Normal	σ	7.899*	5.540*	4.324*	3.886*	3.032	2.725	2.127	1.911	1.340*
								μ	66.39	46.57	36.34	32.66	25.49	22.90	17.87	16.06	11.27
126	T-4	Longitudinal		80	Notched	Recrys-tallize	Weibull	b	2.230*	2.458*	2.458	2.458	2.458	2.458	2.458	2.458*	2.458*
								θ	52.22	37.17	29.30	26.45	20.85	18.81	14.83	13.39	9.527
								X_o	42.67	29.97	23.62	21.32	16.81	15.17	11.96	10.79	7.682

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(EXTRUSIONS)

Composition: See Page 166
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Manufacturing Processes																
127	T-4	Long-Transverse		80	Notched	As is	Weibull	b θ X_o	3.311* 51.43 33.97	3.320* 37.23 24.56	3.231* 29.70 19.78	3.377 26.95 17.67	3.313 21.50 14.19	3.289 19.50 12.91	3.242 15.56 10.35	3.236 14.11 9.399	3.236* 10.21 6.803
128	T-4	Long-Transverse		80	Notched	Recrys-tallize	Weibull	b θ X_o	2.454* 52.58 35.92	2.450 37.38 25.54	2.475 29.44 20.06	2.425 26.56 18.20	2.491 20.93 14.23	2.455 18.88 12.89	2.467 14.87 10.14	2.524 13.42 9.098	2.456* 9.543 6.517
129	T-4			80	1.0	Wrought	L.E.V.	ε M	.1888* 65.80	.2221 55.95	.2487 49.96	.2612 47.58	.2925 42.48	.3071 40.46	.3440 36.13	.3612 34.40	.4247* 29.26
	Effect of Stress Concentration																
130	T-4			80	Notched	Longitudinal	Normal	σ μ	7.899* 66.39	5.540* 46.57	4.324* 36.34	3.886* 32.66	3.032 25.49	2.725 22.90	2.127 17.87	1.911 16.06	1.340* 11.27
131	T-4			80	1.0	Longitudinal	L.E.V.	β M			.2141* 64.96	.2408* 57.76	.3164* 43.96	.3559 39.08	.4677 29.74	.5261 26.44	.7775* 17.89

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(EXTRUSIONS)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING Effect of Surface Finish								
132	T-4	Ground 3 RMS	167	80	1.0		S.E.V.	β	.3850*	.5055	.6114	.6636	.8027	.8712	1.053	1.143	1.501*
								M	71.42	54.40	44.97	41.44	34.26	31.56	26.09	24.04	18.31
133	T-4	M.P. 4 RMS	167	80	1.0		Weibull	b	1.383*	1.403*	1.292	1.276	1.972	1.333	1.143	1.218	1.282*
								θ	59.20	48.67	42.41	39.97	35.02	32.87	28.64	27.00	22.20
								X_o	52.24	42.90	37.57	35.43	29.88	29.06	25.50	23.99	19.67
									Miscellaneous								
134	T-4	LTB	167	80	5.2		Weibull	b	4.265*	4.314	4.294	4.181	4.178	4.332	4.248	4.216	4.323*
								θ	51.19	39.27	32.62	30.12	25.02	23.10	19.19	17.72	13.59
								X_o	32.04	24.44	20.35	19.02	15.81	14.35	12.03	11.15	8.456
135	T-4			80	V-Notch		Normal	σ	4.950*	3.797	3.155	2.913	2.420	2.235	1.857*	1.714*	1.315*
								μ	67.72	51.95	43.17	39.86	33.11	30.57	25.40	23.45	17.99
									PLATE BENDING (Completely Reversed) Miscellaneous								
136	T-3	E.P.	30	80	1.0		Weibull	b	2.629*	2.568*	2.903*	2.739	2.404*	2.277*	2.835*	2.748*	2.655*
								θ	64.90	47.28	37.90	34.45	27.61	25.09	20.12	18.29	13.32
								X_o	60.10	43.85	34.88	31.83	25.69	23.42	18.55	16.89	12.33

S_u = 61-81 ksi
S_y = 45-61 ksi

2024 ALUMINUM (Cont'd)
(EXTRUSIONS)

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
137	T-6	M.P.	60	80	3.4		Weibull	b	2.389*	2.412	2.551	2.513	2.475	2.475	2.475	2.475	2.475*
								θ	52.27	34.39	25.68	22.64	16.89	14.89	11.11	9.803	6.451
								X_o	41.96	27.57	20.36	18.00	13.47	11.88	8.870	7.820	5.146
138	T-3			80	1.0		Weibull	b	1.072*	1.151	1.410	.7409	1.330	.9247	.7388*	1.081*	.6207*
								θ	67.06	47.39	37.25	33.32	26.28	23.56	18.44	16.66	11.72
								X_o	63.28	44.57	34.63	31.74	24.52	22.34	17.56	15.71	11.18

S_u = 67 ksi
S_y = 50 ksi

2024 ALCLAD ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
139			16.7	80	1.0		Weibull	b	1.706*	1.485	1.716*	1.716*	1.716*	1.716*	1.716*	1.716*	1.716*
								θ	58.84	47.27	40.61	38.02	32.64	30.57	26.24	24.57	19.75
								X_o	53.84	43.57	37.15	34.78	29.86	27.96	24.01	22.48	18.07
140		Milled Edges		80	1.0	Cold Drawn	S.E.V.	β	.1980*	.2978*	.3962	.4480	.5959	.6738	.8963*	1.013*	1.524*
								M	63.58	42.27	31.78	28.10	21.13	18.68	14.04	12.42	8.260
141	T-3		20	80	2.5		Weibull	b	1.833*	1.833	1.833	1.833	1.833	1.833	1.833*	1.833*	1.833*
								θ	38.73	24.72	18.07	15.78	11.53	10.08	7.366	6.435	4.108
								X_o	32.98	21.05	15.38	13.44	9.825	8.583	6.272	5.480	3.498

S_u = 55-70 ksi
S_y = 37-52 ksi

2025 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING — Effect of Heat Treatment																
142	HT-5	M.P.	100	80	1.0		Weibull	b	6.340*	5.595*	5.940*	5.888*	6.430*	5.740*	6.392	6.392	5.740*
								θ	55.25	44.81	38.71	36.34	31.40	29.48	25.47	23.91	19.39
								X_o	45.65	37.84	32.36	30.43	25.87	24.79	21.01	19.72	16.30
143	T-6	M.P.	167	80	1.0		Weibull	b	1.148*	.9687*	1.340	1.214	1.433	1.127	.9368	1.059	1.481*
								θ	65.43	51.47	43.60	40.54	34.33	31.89	26.97	25.09	19.79
								X_o	60.91	48.09	40.36	37.67	31.68	29.71	25.21	23.41	18.23
144	HT-6	Electropolish	167	80	1.0		Weibull	b	1.552*	1.552*	1.552*	1.552*	1.552	1.552	1.619*	1.552*	1.552*
								θ	55.83	42.09	34.54	31.73	26.04	23.91	19.63	18.03	13.59
								X_o	52.59	39.64	32.53	29.88	24.52	22.52	18.46	16.98	12.80
145	HT-7	Electropolish	167	80	1.0		Weibull	b	1.451*	1.563*	1.467*	1.429*	1.346	1.581	1.518	1.493	1.419*
								θ	45.17	36.94	32.05	30.15	26.16	24.66	21.40	20.13	16.44
								X_o	38.33	31.08	27.16	25.62	22.36	20.72	18.07	17.03	13.98
	Effect of Surface Treatment																
146	HT-5	MP As is	100	80	1.0		Weibull	b	6.340*	5.595*	5.940*	5.888*	6.430*	5.740*	6.392	6.392	5.740*
								θ	55.25	44.81	38.71	36.34	31.40	29.48	25.47	23.91	19.39
								X_o	45.65	37.84	32.36	30.43	25.87	24.79	21.01	19.72	16.30
147	HT-5	MP-Anodized	167	80	1.0		Weibull	b	1.498*	1.498*	1.498*	1.498*	1.498*	1.498*	1.498	1.498	1.498*
								θ	53.36	44.63	39.39	37.32	32.94	31.22	27.55	26.11	21.84
								X_o	47.84	40.01	35.31	33.46	29.54	27.99	24.70	23.41	19.58

S_u = 55-70 ksi
S_y = 37-52 ksi

2025 ALUMINUM (Cont'd)

Composition: See Page 165
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Stress Concentration																
148	HT-5	MP	100	80	1.0		Weibull	b	6.340*	5.595*	5.940*	5.888*	6.430*	5.740*	6.392	6.392	5.740*
								θ	55.25	44.81	38.71	36.34	31.40	29.48	25.47	23.91	19.39
								X_o	45.65	37.84	32.36	30.43	25.87	24.79	21.01	19.72	16.30
149	HT-5	MP	100	80	1.9		Weibull	b		10.11*	10.49*	9.399*	9.341*	10.40*	10.07	9.826	8.494*
								θ		62.37	51.67	47.65	39.47	36.40	30.16	27.81	21.24
								X_o		42.23	34.40	33.27	27.63	24.34	20.45	19.06	15.40
	AXIAL (Completely Reversed) Effect of Stress Concentration																
150	HT-5	M.P.	100	80	1.0		S.E.V.	β	.5422*	.6644*	.7657*	.8140*	.9381	.9973	1.149	1.221	1.497
								M	51.68	42.18	36.59	34.42	29.87	28.10	24.38	22.93	18.71
151	HT-5	M.P.	100	80	1.9		Weibull	b	.6534*	.7215*	1.027*	.9060*	.5325*	.9701*	.7629	.6592	.9261*
								θ	27.98	21.02	17.27	15.82	12.87	11.88	9.688	8.870	6.684
								X_o	25.73	19.27	15.58	14.37	11.87	10.75	8.865	8.154	6.064

HT-5: Solution H.T., 960°F, 1 hr; W.Q., Aged 340°F 10 hrs., A.C.
HT-6: Reheat 370°F 3/4 hrs., W.Q., Aged 330°F 15 hrs.
HT-7: Solution H.T., 916-930°F, Aged 210°F-6 hrs. A.C., Reheat to 315°F 10-hrs. A.C.

S_u = 77.5 ksi
S_y = 60.5 ksi

2026 ALUMINUM

Composition: See Page 166
(*) Extrapolated

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
152	Fully Heat Treated			80	1.0		Normal	σ μ	2.485* 49.12	2.140* 42.30	1.928* 38.10	1.843 36.42	1.660 32.81	1.587 31.36	1.429 28.25	1.366 27.01	1.177* 23.26
153	Fully Heat Treated			80	Ho-N	Transv. Hole	Normal	σ μ	2.855* 34.24	2.197* 26.35	1.829* 21.94	1.691 20.27	1.408 16.88	1.301 15.60	1.083 12.99	1.001 12.00	.7706* 9.241

Life-in-cycles columns: FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES

S_u = 59—67 ksi
S_y = 46—54 ksi

2219 ALUMINUM

Composition: See Page 165
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed)																
	Effect of Heat Treatment																
154	T-87	M.P.		80	1.0	Hot Rolled	Weibull	b θ X_o	6.559* 53.99 30.99	6.455 41.06 23.81	6.029 33.91 20.46	6.218 31.28 18.52	5.979 25.79 15.63	5.798 23.75 14.63	5.463* 19.61 12.44	5.368* 18.06 11.55	5.206* 13.73 8.911
155	T-62	M.P.		80	1.0	Hot Rolled	S.E.V.	β M	.3830* 39.51	.4826 31.35	.5672 26.67	.6081 24.88	.7148 21.17	.7663 19.74	.9007* 16.80	.9656* 15.67	1.216* 12.43
	Effect of Stress Concentration																
156	T-62	M.P.		80	1.0		S.E.V.	β M	.3830* 39.51	.4826 31.35	.5672 26.67	.6081 24.88	.7148 21.17	.7663 19.74	.9007* 16.80	.9656* 15.67	1.216* 12.43
157	T-62	M.P.		80	3.5		Normal	σ μ	2.014* 28.56	1.268 17.97	.9173 13.00	.7979 11.31	.5773 8.183	.5021 7.118	.3633* 5.150	.3160* 4.479	.1988* 2.819
	Effect of Test Temperature																
158				400	1.0		Normal	σ μ	3.431* 61.03	2.659* 47.30	2.225 39.58	2.061 36.66	1.724 30.67	1.597 28.41	1.336 23.77	1.238 22.02	.9595* 17.06
159				600	1.0		S.E.V.	β M	.4197* 42.33	.5413* 32.82	.6467 27.47	.6982 25.44	.8341 21.30	.9005 19.73	1.075 16.51	1.161 15.29	1.498* 11.86

S_u = 47—61 ksi
S_y = 41—52 ksi

2618 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
ROTARY BEAM BENDING — Effects of Heat Treatment and Manufacturing Processes																	
160	T-61	Mechanical Polish - 4 RMS	83	80	1.0	Hammer Forged	L.E.V.	β M		.6513 51.65	.7902 42.57	.8588 39.17	1.041 32.28	1.132 29.70	1.373 24.48	1.493* 22.53	1.968* 17.08
161	T-6	Mechanical Polish - 4 RMS	83	80	1.0	Hot Rolled	L.E.V.	β M		.4545 51.13	.5614 41.39	.6149 37.79	.7596 30.59	.8320 27.93	1.027* 22.61	1.125* 20.64	1.522* 15.26
Effect of Stress Concentration																	
162	T-6	Mechanical Polish - 4 RMS	83	80	1.0	Hot Rolled	L.E.V.	β M		.4545 51.13	.5614 41.39	.6149 37.79	.7596 30.59	.8320 27.93	1.027* 22.61	1.125* 20.64	1.522* 15.26
163	T-6	Mechanical Polish - 4 RMS	83	80	2.4	Hot Rolled	Weibull	b θ X_o	2.532* 53.05 48.16	2.408 35.77 32.57	2.509 27.16 24.67	2.401 24.12 21.97	2.248* 18.31 16.73	2.248* 16.26 14.86	2.248* 12.34 11.28	2.248* 10.96 10.02	2.248* 7.394 6.759
Effect of Test Temperature																	
164	T-61	Mechanical Polish - 4 RMS	83	250	2.4	Hammer Forged	S.E.V.	β M		.3122 38.57	.4522 26.63	.5304 22.71	.7682 15.68	.9011 13.36	1.305* 9.231	1.530* 7.870	2.600* 4.633
165	T-61	Mechanical Polish - 4 RMS	83	400	2.4	Hammer Forged	Weibull	b θ X_o	4.679* 53.13 44.05	4.701 33.87 28.06	4.529 24.72 20.60	4.530 21.59 17.99	4.529 15.76 13.13	4.530 13.76 11.47	4.530 10.04 8.375	4.529 8.773 7.313	4.529* 5.593 4.662

S_u = 47—61 ksi
S_y = 41—52 ksi

2618 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
166	T-6	Mechanical Polish 4 RMS	83	80	1.0	Hot Rolled	L.E.V.	β		.4545	.5614	.6149	.7596	.8320	1.027*	1.125*	1.522*
								M		51.13	41.39	37.79	30.59	27.93	22.61	20.64	15.26
167	T-6	Mechanical Polish 4 RMS	83	250	1.0	Hot Rolled	Weibull	b		5.376	5.519	5.750	5.565	5.250	5.847	5.847*	5.848*
								θ		52.19	41.46	37.55	29.83	27.01	21.46	19.44	13.98
								X_o		45.52	36.05	32.47	25.91	23.63	18.52	16.77	12.07
168	T-6	Mechanical Polish 4 RMS	83	400	1.0	Hot Rolled	Normal	σ		2.659	2.104	1.902	1.505	1.361	1.077	.9738	.6967*
								μ		47.71	37.76	34.13	27.01	24.42	19.32	17.47	12.50

PLATE BENDING (Completely Reversed)
Effect of Frequency

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
169		Polished	24	80	1.0		S.E.V.	β	.5826*	.6536*	.7082*	.7331*	.7944	.8224	.8911	.9225	1.034*
								M	35.01	31.21	28.81	27.83	25.68	24.81	22.89	22.11	19.71
170		Polished	370	80	1.0		Weibull	b	5.996*	5.809*	5.531*	5.427*	5.217	5.137	4.976	4.916	4.809*
								θ	41.46	35.61	32.02	30.59	27.50	26.27	23.63	22.57	19.39
								X_o	24.36	21.32	19.69	19.00	17.43	16.77	15.30	14.70	12.75
171		Polished	850	80	1.0		S.E.V.	β	.4651*	.5371*	.5940*	.6203*	.6860*	.7163	.7922	.8273	.9554*
								M	41.41	35.86	32.42	31.05	28.08	26.88	24.31	23.28	20.16

S_u = [illegible] ksi
S_y = [illegible] ksi

2618 ALUMINUM (Cont'd)

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	PLATE BENDING (Completely Reversed) Effect of Frequency																
172		Polished	1550	80	1.0		Normal	σ	1.992*	1.773*	1.634*	1.577*	1.454*	1.404*	1.294	1.249	1.111*
								μ	35.50	31.59	29.12	28.11	25.91	25.02	23.06	22.26	19.81
173		Polished	3835	80	1.0		Weibull	b		1.242*	1.295*	1.295*	1.295*	1.412*	1.133	1.165	1.508
								θ		60.18	49.38	45.32	37.14	34.20	27.85	25.58	19.41
								X_o		48.17	39.28	36.05	29.54	26.76	22.53	20.63	14.94
	AXIAL (Completely Reversed) Effect of Stress Concentration																
174	HT-8			392	1.0		Weibull	b	1.465*	1.365*	1.214*	1.152	1.006	.9412	.7585	.7423	.7423*
								θ	15.30	12.58	10.96	10.32	8.997	8.478	7.383	6.960	5.723
								X_o	14.50	11.95	10.46	9.883	8.646	8.161	7.135	6.728	5.532
175	HT-8			392	Ho-N	Transv. Hole	L.E.V.	β	1.848*	2.382*	2.844	3.070	3.666	3.957	4.724	5.099	6.572*
								M	12.34	9.578	8.022	7.432	6.224	5.767	4.830	4.474	3.472

HT-8: A.C. from 986°F, Annealed at 680°F for 2 hrs and cooled at 18°F/hr to 80°F

5052 ALUMINUM

Composition: See Page 16[illegible]
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Heat Treatment

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
176	H-34	Mechanical Polish	33	80	1.0	Hot Rolled	Weibull	b	2.968*	2.907*	3.001	2.948	3.070	3.029	2.942*	3.025*	3.045*
								θ	45.20	35.88	30.54	28.48	24.24	22.61	19.24	17.95	14.25
								X_o	33.74	26.92	22.73	21.29	17.94	16.79	14.39	13.33	10.57
177	H-32	Mechanical Polish	33	80	1.0	Hot Rolled	Weibull	b	2.058*	2.001*	2.001	2.040	2.001	2.001	2.038*	2.002*	2.001*
								θ	45.82	36.54	31.19	29.15	24.88	23.24	19.85	18.54	14.79
								X_o	36.90	29.55	25.23	23.50	20.12	18.80	16.01	14.99	11.96

S_u = 36 ksi
S_y = 18 ksi

5056 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
178				80	1.0	Rolled	Weibull	b	1.946*	1.946*	1.946	1.946	1.946	1.946	1.946	1.934*	2.067*
								θ	34.27	30.36	27.90	26.90	24.72	23.84	21.90	21.12	18.72
								X_o	27.66	24.51	22.52	21.71	19.95	19.24	17.68	17.06	14.96
179				80	Ho-N	Rolled	S.E.V.	β	.3249*	.4206*	.5039	.5446	.6524	.7051	.8447*	.9130*	1.182*
								M	24.35	18.81	15.70	14.52	12.12	11.22	9.367	8.667	6.694

$S_u = 50$ ksi
$S_y = 34.4$ ksi

5083 ALUMINUM

Composition: See Page 166
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						**FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS** — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Miscellaneous																
180	H-113			80	1.0		Weibull	b θ X_o			1.440 44.44 42.78	1.669 40.78 39.06	1.490* 33.33 32.05	1.069* 30.52 29.58	1.355* 24.98 24.09	.9732* 22.88 22.21	1.669* 17.20 16.48

$S_u = 45$ ksi
$S_y = 30$ ksi

5086 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING Miscellaneous																
181	H-34	M.P.	33	80	1.0		Normal	σ μ		2.372* 37.03	1.990 31.06	1.845 28.79	1.547 24.15	1.434 22.39	1.203 18.78	1.115* 17.41	.8675* 13.53
	PLATE BENDING Effect of Heat Treatment																
182	H-112	Ground and Milled Edges	33	80	1.0		S.E.V.	β M	.6659* 26.85	.8964 19.94	1.103* 16.20	1.206* 14.82					
183	H-32	Ground and Milled Edges	33	80	1.0		L.E.V.	β M	.2892* 25.34	.4526 16.19	.6190* 11.84	.7083* 10.34					

5154 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
184	H-34			80	1.0	Tubes	Weibull	b θ X_o	1.578* 50.28 44.64	1.578 33.60 29.83	1.578 25.35 22.50	1.578 22.45 19.93	1.578 16.94 15.04	1.578 15.00 13.32	1.578* 11.32 10.05	1.578* 10.02 8.902	1.578* 6.700 5.949

(TEST CONDITIONS: Heat Treat, Surf. Fin., Freq., Temp °F, K_t, Other; FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS: DIST., Param., LIFE IN CYCLES)

6061 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Surface Finish

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
185	T-6			80	1.0	Tubes	S.E.V.	β M	.1412* 64.79	.2361 38.76	.3381 27.07	.3946 23.19	.5651 16.19	.6596 13.87	.9445 9.690	1.102 8.301	1.842* 4.966
186	T-6	Polish		80	1.0		Weibull	b θ X_o	1.052* 55.90 53.04	1.553* 45.85 42.76	1.261* 39.77 37.48	1.291* 37.44 35.25	.9313 32.45 30.89	.8536 30.53 29.12	1.189 26.58 25.11	1.136 25.01 23.67	.9662* 20.43 19.43
187	T-6	Machine		80	1.0		S.E.V.	β M	.2969* 53.90	.3567* 44.85	.4056* 39.45	.4287 37.32	.4874 32.83	.5152 31.06	.5858 27.32	.6191 25.85	.7439* 21.51
188	T-6	As Rolled		80	1.0		S.E.V.	β M	.1829* 79.67	.2725* 53.46	.3602* 40.45	.4062* 35.87	.5368 27.14	.6053 24.07	.8000* 18.21	.9021* 16.15	1.344* 10.83

S_u = 47-56 ksi
S_y = 29-33 ksi

5456 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Miscellaneous																
189	H-311			80	1.0		L.E.V.	β		1.041	1.328*	1.474*	1.880*	2.088*	2.662*	2.956*	4.185*
								M		40.91	32.08	28.89	22.66	20.41	16.00	14.41	10.18
	AXIAL (Completely Reversed) — Effect of Heat Treatment																
190	H-311			80	1.0		Weibull	b	7.549	7.122	6.198	6.437	6.235	6.160*	6.011*	5.956*	5.806*
								θ	54.49	40.15	32.42	29.58	23.89	21.79	17.60	16.05	11.83
								X_o	36.09	27.27	23.23	20.90	17.08	15.64	12.74	11.65	8.661
191	H-321			80	1.0		Weibull	b		1.303*	1.481	1.560	1.562	1.562	.9340	1.135*	.8119*
								θ		50.29	45.47	43.54	39.29	37.59	33.62	32.28	27.70
								X_o		45.09	40.30	38.38	34.63	33.13	30.83	29.25	25.57
	Miscellaneous																
192	H-343			80	3.5	Hot Rolled	S.E.V.	β	.4771*	.7212	.9626	1.090	1.454	1.647	2.199*	2.490*	3.763*
								M	27.79	18.39	13.78	12.16	9.117	8.051	6.032	5.326	3.524

S_u = 100 ksi
S_y = 90 ksi

7001 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp°F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	AXIAL (Completely Reversed) Effect of Grain Direction																
193	T-75 Die Forged	Machined	30	80	1.0	Longitudinal	Normal	σ	4.707*	3.681	3.099	2.878	2.424	2.251	1.895	1.760*	1.376*
								μ	60.65	47.43	39.94	37.09	31.23	29.00	24.42	22.68	17.73
194	T-75 Die Forged	Machined	30	80	1.0	Transv.	Weibull	b	2.289*	2.198	2.318	2.282	2.208	2.198	2.198	2.198*	2.198*
								θ	63.12	50.58	43.34	40.55	34.73	32.50	27.84	26.04	20.87
								X_o	54.83	44.10	37.60	35.23	30.27	28.33	24.27	22.71	18.20
195	T-75 Hand Forged	Machined	30	80	1.0	Longitudinal	Weibull	b	3.364*	3.457*	3.485	3.389	3.279	3.528	3.446	3.414*	3.322*
								θ	62.22	50.02	42.94	40.20	34.51	32.32	27.74	25.97	20.87
								X_o	47.85	38.24	32.76	30.87	26.68	24.59	21.22	19.91	16.10
196	T-75 Hand Forged	Machined	30	80	1.0	Transv.	Weibull	b	4.195*	4.276	3.864	4.163	3.961	3.911	4.254	4.215*	4.101*
								θ	62.79	50.27	43.03	40.25	34.45	32.22	27.59	25.80	20.66
								X_o	51.31	40.94	35.65	32.94	28.43	26.64	22.49	21.07	16.95
197	T-75 Hand Forged	Machined	30	80	3.0	Longitudinal	Weibull	b	2.108*	2.065*	2.065	2.065	2.065	2.065*	2.065*	2.065*	2.065*
								θ	33.85	22.07	16.36	14.38	10.66	9.380	6.956	6.115	3.987
								X_o	29.76	19.43	14.41	12.67	9.396	8.261	6.126	5.385	3.511
198	T-75	Machined	30	80	3.0	Transv.	L.E.V.	β	.5115*	.7506*	.9813	1.101	1.439*	1.616*	2.112*	2.371*	3.479*
								M	29.65	20.20	15.45	13.77	10.53	9.387	7.180	6.397	4.360

S_u = 100 ksi
S_y = 90 ksi

7001 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS: DIST.	Param.	LIFE IN CYCLES: $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed)																
	Effect of Grain Direction																
199	T-75 Die Forged	Machined	30	80	3.0	Longi-tudinal	Normal	σ	2.799*	1.812	1.338	1.174	.8665*	.7603*	.5612*	.4924*	.3188*
								μ	34.83	22.56	16.65	14.61	10.78	9.462	6.984	6.128	3.968
200	T-75 Die Forged	Machined	30	80	3.0	Transv.	Normal	σ	5.308*	3.597	2.741	2.438	1.857*	1.652*	1.258*	1.119*	.7588*
								μ	36.72	24.88	18.96	16.86	12.85	11.43	8.708	7.746	5.249
	Effect of Stress Concentration																
201	T-75 Hand Forged	Machined	30	80	1.0	Longitudinal	Weibull	b	3.364*	3.457*	3.485	3.389	3.279	3.528	3.446	3.414*	3.322*
								θ	62.22	50.02	42.94	40.20	34.51	32.32	27.74	25.97	20.87
								X_o	47.85	38.24	32.76	30.87	26.68	24.59	21.22	19.91	16.10
202	T-75 Hand Forged	Machined	30	80	3.0	Longitudinal	Weibull	b	2.108*	2.065*	2.065	2.065	2.065	2.065*	2.065*	2.065*	2.065*
								θ	33.85	22.07	16.36	14.38	10.66	9.380	6.956	6.115	3.987
								X_o	29.76	19.43	14.41	12.67	9.396	8.261	6.126	5.385	3.511
203	T-75 Hand Forged	Machined	30	80	1.0	Transverse	Weibull	b	4.195*	4.276	3.864	4.163	3.961	3.911	4.254	4.215*	4.101*
								θ	62.79	50.27	43.03	40.25	34.45	32.22	27.59	25.80	20.66
								X_o	51.31	40.94	35.65	32.94	28.43	26.64	22.49	21.07	16.95
204	T-75 Hand Forged	Machined	30	80	3.0	Transverse	L.E.V.	β	.5115*	.7506*	.9813	1.101	1.439*	1.616*	2.112*	2.371*	3.479*
								M	29.65	20.20	15.45	13.77	10.53	9.387	7.180	6.397	4.360

S_u = 100 ksi
S_y = 90 ksi

7001 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Stress Concentration																
205	T-75 Die Forged	Machined	30	80	1.0	Longitudinal	Normal	σ μ	4.707* 60.65	3.681 47.43	3.099 39.94	2.878 37.09	2.424 31.23	2.251 29.00	1.895 24.42	1.760* 22.68	1.376* 17.73
206	T-75 Die Forged	Machined	30	80	3.0	Longitudinal	Normal	σ μ	2.799* 34.83	1.812 22.56	1.338 16.65	1.174 14.61	.8665* 10.78	.7603* 9.462	.5612* 6.984	.4924* 6.128	.3188* 3.968
207	T-75 Die Forged	Machined	30	80	1.0	Transverse	Weibull	b θ X_o	2.289* 63.12 54.83	2.198 50.58 44.10	2.318 43.34 37.60	2.282 40.55 35.23	2.208 34.73 30.27	2.198 32.50 28.33	2.198 27.84 24.27	2.198* 26.04 22.71	2.198* 20.87 18.20
208	T-75 Die Forged	Machined	30	80	3.0	Transverse	Normal	σ μ	5.308* 36.72	3.597 24.88	2.741 18.96	2.438 16.86	1.857* 12.85	1.652* 11.43	1.258* 8.708	1.119* 7.746	.7588* 5.249
	Miscellaneous																
209	T-6	17 RMS	30	80	1.0	Extrusion	Normal	σ μ	5.073* 72.27	3.946* 56.22	3.310 47.17	3.069 43.73	2.575 36.69	2.387 34.02	2.003 28.54	1.857 26.46	1.444* 20.58

S_u = 64 ksi
S_y = 58 ksi

7039 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
210	T-6			80	1.0	Hot Rolled	Normal	σ μ		3.715* 43.51	2.482 29.06	2.086 24.43	1.393* 16.32	1.171* 13.72	.7827* 9.167		
211	T-6			80	3.5	Hot Rolled	Weibull	b θ X_o	3.756* 29.29 14.67	3.611 18.07 9.320	3.475 12.89 6.824	3.430 11.15 5.950	3.349 7.956 4.310	3.321 6.880 3.745	3.270* 4.909 2.697	3.270* 4.245 2.332	3.270* 2.619 1.439
212	T-6			80	8.0	Hot Rolled	Weibull	b θ X_o	1.707* 46.15 23.01	1.750 25.47 12.35	1.762 16.80 8.080	1.762 14.03 6.751	1.762 9.248 4.448	1.762* 7.727 3.716	1.762* 5.091 2.448	1.762* 4.254 2.045	1.762* 2.341 1.126

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM
(PLATE AND SHEET)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS (LIFE IN CYCLES)										
	PLATE BENDING (Completely Reversed) Effect of Stress Concentration																
213	T-6	Ground	6	80	7.4		Weibull	b θ X_o	1.174* 62.73 51.47	1.517 28.12 19.93	1.567* 15.72 10.85	1.580* 12.23 8.377	1.583* 6.805 4.654	1.583* 5.286 3.615	1.583* 2.940 2.011	1.583* 2.284 1.562	1.583* .9869 .6750
214	T-6	Ground	6	80	7.9		Weibull	b θ X_o	1.043* 45.30 36.95	1.563 26.12 19.29	1.677 17.62 12.56	1.698 14.85 10.51	1.735* 9.982 6.976	1.743* 8.407 5.858	1.743* 5.636 3.928	1.743* 4.745 3.306	1.743* 2.678 1.866
	AXIAL (Completely Reversed) Miscellaneous																
215		Milled Edges		80	4.0		L.E.V.	β M	.4353* 24.62	.6132 17.47	.7792 13.75	.8638 12.40	1.097 9.764	1.216 8.807	1.546 6.931	1.714 6.252	2.414* 4.438
216	T-6	Milled Edges	24	80	4.0	Hot Rolled	Weibull	b θ X_o	1.500* 27.15 19.66	1.557 19.51 14.03	1.508 15.47 11.19	1.489 14.00 10.15	1.618 11.13 7.938	1.618 10.07 7.185	1.618* 7.994 5.702	1.618* 7.236 5.161	1.618* 5.198 3.707

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(PLATE AND SHEET)

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1×10^3	1×10^4	5×10^4	1×10^5	5×10^5	1×10^6	5×10^6	1×10^7	1×10^8
217	T-6	Electropolished	6	80	2.2		Weibull	b	1.774*	2.063*	1.481	1.250*	1.486*	1.358*	1.468*	1.387	1.566*
								θ	48.06	29.48	20.78	17.90	12.71	10.95	7.775	6.701	4.104
								X_o	40.61	24.31	17.93	15.62	10.96	9.515	6.712	5.812	3.521
218	T-6	Electropolished	24	80	2.8		Weibull	b	1.656*	1.547	1.744	.7944*	.8959*	.9405*	1.065*	.9338*	1.111*
								θ	41.60	25.51	18.19	15.47	11.02	9.528	6.792	5.859	3.604
								X_o	36.79	22.74	15.98	14.41	10.23	8.822	6.248	5.419	3.307
219	T-6	Electropolished	24	80	2.9		Normal	σ	3.743*	2.351	1.698	1.476*	1.066*	.9274*	.6700*	.5824*	.3658*
								μ	41.80	26.25	18.96	16.48	11.91	10.35	7.481	6.504	4.085
220	T-6	Electropolished and Milled Edges		80	1.5	Hot Rolled	Weibull	b	1.308*	1.721*	1.580	1.525	1.407	1.361	1.344	1.344	1.344*
								θ	49.37	37.70	31.16	28.71	23.74	21.87	18.09	16.67	12.70
								X_o	44.97	33.79	28.10	25.94	21.54	19.88	16.45	15.16	11.56
221	T-6	Electropolished and Milled Edges		80	1.0	Hot Rolled	L.E.V.	β	.2000*	.2434*	.2792	.2962	.3398	.3605	.4135	.4387*	.5339*
								M	49.84	40.96	35.71	33.66	29.34	27.66	24.11	22.73	18.68
222	T-6	Electropolished and Milled Edges		80	2.0	Hot Rolled	Weibull	b	3.406*	3.441	3.516	3.461	3.350	3.310	3.463*	3.435*	3.406*
								θ	44.10	31.29	24.62	22.20	17.46	15.74	12.39	11.17	7.929
								X_o	31.56	22.32	17.45	15.81	12.55	11.36	8.826	7.979	5.674

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(PLATE AND SHEET)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1×10^3	1×10^4	5×10^4	1×10^5	5×10^5	1×10^6	5×10^6	1×10^7	1×10^8
	TEST CONDITIONS						**FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS** — LIFE IN CYCLES										
	AXIAL (Completely Reversed) — Effect of Stress Concentration																
223	T-6	Electropolish Milled Edges	25	80	4.0	Hot Rolled	Weibull	b θ X_o	1.500* 27.15 19.66	1.557 19.51 14.03	1.508 15.47 11.19	1.489 14.00 10.15	1.618 11.13 7.938	1.618 10.07 7.185	1.618* 7.994 5.702	1.618* 7.236 5.161	1.618* 5.198 3.707
224	T-6	Electropolish Milled Edges	25	80	5.0	Hot Rolled	L.E.V.	β M	.5336* 24.20	.8056 16.03	1.074 12.01	1.216 10.61	1.622 7.961	1.836 7.033	2.448 5.273	2.772* 4.658	4.185* 3.085
225	T-6	Mechanical Polishing	25	80	1.0	Hot Rolled	Weibull	b θ X_o	1.933* 73.23 62.71	1.966 42.90 36.67	1.966 29.52 25.23	1.966 25.13 21.48	1.966 17.29 14.78	1.966 14.72 12.58	1.966* 10.12 8.658	1.966* 8.622 7.370	1.966* 5.050 4.317
226	T-6	Mechanical Polishing	25	80	3.5	Hot Rolled	Normal	σ μ	3.029* 33.73	1.939 21.59	1.419 15.80	1.241 13.81	.9085 10.11	.7942* 8.844	.5814* 6.474	.5083* 5.660	.3253* 3.622
	Effect of Surface Finish																
227	T-6	E.P.	18.3	80	1.0	Hot Rolled	L.E.V.	β M	.2000* 49.84	.2434* 40.96	.2792 35.71	.2962 33.66	.3398 29.34	.3605 27.66	.4135 24.11	.4387* 22.73	.5339* 18.68
228	T-6	M.P.	25	80	1.0	Hot Rolled	Weibull	b θ X_o	1.933* 73.23 62.71	1.966 42.90 36.67	1.966 29.52 25.23	1.966 25.13 21.48	1.966 17.29 14.78	1.966 14.72 12.58	1.966* 10.12 8.658	1.966* 8.622 7.370	1.966* 5.050 4.317

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM
(BAR)

Composition: See Page 167
(*) Extrapolated Values

Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Grain Direction																
229	T-6			80	1.0	Longi-tudinal	Weibull	b	2.668*	2.740*	2.839*	2.820*	2.776	2.758	2.718	2.702	2.651*
								θ	39.95	35.97	33.43	32.39	30.09	29.15	27.09	26.24	23.62
								X_o	32.38	29.02	26.80	26.00	24.22	23.50	21.88	21.22	19.17
230	T-6			80	1.0	Trans-verse	Weibull	b	1.278*	1.367*	1.285*	1.301	1.302	1.302	1.302*	1.302*	1.326*
								θ	70.42	47.85	36.45	32.44	24.74	22.02	16.79	14.94	10.14
								X_o	49.54	33.21	25.62	22.75	17.34	15.43	11.77	10.47	7.087

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(BAR)

Composition: See Page 167
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Frequency

Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
231	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Machanical Polishing	5.3	80	1.0		Weibull	b θ X_o	1.746* 76.10 63.29	1.619* 58.70 49.25	1.560 48.96 41.24	1.573 45.30 38.12	1.496 37.78 31.94	1.517 34.95 29.51	1.721 29.20 24.33	1.680* 27.01 22.56	1.557* 20.83 17.55
232			20	80	1.0		Normal	σ μ	7.583* 77.57	5.836* 59.70	4.859 49.71	4.491 45.94	3.740 38.26	3.456 35.35	2.878 29.44	2.660 27.21	2.047* 20.94
233			62.5	80	1.0		Weibull	b θ X_o	6.228* 66.73 38.14	5.594* 55.23 33.60	5.980 48.41 28.37	5.943 45.73 26.90	5.866 40.08 23.75	5.835 37.86 22.51	5.578 33.18 20.21	5.483 31.34 19.27	5.256* 25.95 16.29
234			5.3	80	2.0		Weibull	b θ X_o	2.075* 46.59 41.10	2.275* 36.11 31.56	2.166 30.20 26.53	2.125 27.97 24.62	2.040 23.39 20.67	2.007 21.66 19.17	2.000* 18.12 16.04	2.000* 16.78 14.86	2.000* 13.00 11.51
235			20	80	2.0		L.E.V.	β M	.2298* 46.13	.3016 35.15	.3648 29.07	.3959 26.78	.4787 22.15	.5196 20.41	.6283 16.87	.6819 15.55	.8949* 11.85
236			62.5	80	2.0		Normal	σ μ	5.612* 33.75	4.646* 27.94	4.071 24.48	3.846 23.13	3.370 20.27	3.183 19.14	2.789 16.77	2.635 15.85	2.181* 13.12

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(BAR)

Composition: See Page 167
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
237	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	5.3	80	1.0		Weibull	b θ X_o	1.746* 76.10 63.29	1.619* 58.70 49.25	1.560 48.96 41.24	1.573 45.30 38.12	1.496 37.78 31.94	1.517 34.95 29.51	1.721 29.20 24.33	1.680* 27.01 22.56	1.557* 20.83 17.55
238	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	5.3	80	2.0		Weibull	b θ X_o	2.075* 46.59 41.10	2.275* 36.11 31.56	2.166 30.20 26.53	2.125 27.97 24.62	2.040 23.39 20.67	2.007 21.66 19.17	2.000* 18.12 16.04	2.000* 16.78 14.86	2.000* 13.00 11.51
239	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	20	80	1.0		Normal	σ μ	7.583* 77.57	5.836* 59.70	4.859 49.71	4.491 45.94	3.740 38.26	3.456 35.35	2.878 29.44	2.660 27.21	2.047* 20.94
240	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	20	80	2.0		L.E.V.	β M	.2298* 46.13	.3016 35.15	.3648 29.07	.3959 26.78	.4787 22.15	.5196 20.41	.6283 16.87	.6819 15.55	.8949* 11,85
241	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	62.5	80	1.0		Weibull	b θ X_o	6.228* 66.73 38.14	5.594* 55.23 33.60	5.980 48.41 28.37	5.943 45.73 26.90	5.866 40.08 23.75	5.835 37.86 22.51	5.578 33.18 20.21	5.483 31.34 19.27	5.256* 25.95 16.29
242	W.Q. from 876°F, Aged at 250°F, 24 hrs.	Mechanical Polished	62.5	80	2.0		Normal	σ μ	5.612* 33.75	4.646* 27.94	4.071 24.48	3.846 23.13	3.370 20.27	3.183 19.14	2.789 16.77	2.635 15.85	2.181* 13.12

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(BAR)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Stress Concentration																
243	T-6			80	1.0	Longitudinal	Weibull	b θ X_o	2.668* 39.95 32.38	2.740* 35.97 29.02	2.839* 33.43 26.80	2.820* 32.39 26.00	2.776 30.09 24.22	2.758 29.15 23.50	2.718 27.09 21.88	2.702 26.24 21.22	2.651* 23.62 19.17
244	T-6			80	Notch	Longitudinal	Weibull	b θ X_o	2.024* 27.80 24.76	1.912 23.82 21.31	1.842* 21.38 19.18	1.814* 20.40 18.33	1.752 18.31 16.49	2.170 17.50 15.49	2.122 15.70 13.93	2.120 14.99 13.30	2.120* 12.84 11.39
	AXIAL (Completely Reversed) Effect of Stress Concentration																
245	T-6	Ground - 10 RMS	60	80	1.0		L.E.V.	β M	.1804* 79.93	.3207 44.96	.4795 30.08	.5701 25.29	.8523* 16.92	1.013* 14.23	1.515* 9.519	1.801* 8.005	3.202* 4.503
246	T-6	Ground - 10 RMS	60	80	3.4		L.E.V.	β M	.2129* 28.95	.3014 20.46	.3842 16.05	.4265 14.45	.5437 11.34	.6036 10.21	.7695 8.014	.8543 7.219	1.209* 5.101

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(BAR)

Composition: See Page 1627
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

✝Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
247	T-6	Electropolish	30	80	1.0		Weibull	b	1.622*	1.193	.9867	1.168	1.244	1.297	1.387	1.416	1.475*
								θ	74.18	49.63	37.73	33.52	25.51	22.70	17.29	15.38	10.40
								X_o	55.54	39.17	30.08	26.51	20.05	17.74	13.37	11.85	7.959
248	T-6	Electropolish	30	80	2.0		Weibull	b	1.954	1.747	2.050	1.982	1.890	1.890	1.890*	1.890*	1.890*
								θ	44.19	30.09	23.02	20.51	15.68	13.97	10.68	9.516	6.483
								X_o	39.03	26.76	20.26	18.09	13.88	12.36	9.457	8.425	5.739

Columns: TEST CONDITIONS (Heat Treat through Other); FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES.

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM
(EXTRUSIONS AND FORGINGS)

Composition: See Page 167
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Frequency

✝Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
249		Mechanical & Electropolish	167	80	1.0	Extruded	Weibull	b	1.466*	1.561*	1.506	1.526	1.568	1.585	1.618	1.631	1.669*
								θ	53.04	44.98	40.04	38.10	33.95	32.30	28.78	27.38	23.21
								X_o	38.19	32.05	28.71	27.26	24.17	22.95	20.36	19.34	16.31
250		Mechanical & Electropolish	50	80	1.0	Extruded	Normal	σ	7.953*	6.175	5.175*	4.795	4.018	3.723	3.120	2.891	2.245*
								μ	67.01	52.03	43.60	40.40	33.85	31.37	26.28	24.36	18.91
251		Mechanical & Electropolish	20	80	1.0	Extruded	Normal	σ	7.743*	6.515*	5.775	5.482	4.859	4.613	4.088	3.881	3.266*
								μ	48.19	40.55	35.94	34.12	30.24	28.71	25.44	24.16	20.32

S_u = 71-87 ksi
S_y = 67-79 ksi

7075 ALUMINUM (Cont'd)
(EXTRUSIONS AND FORGINGS)

Composition: See Page 167
(*) Extrapolated

†Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING — Effect of Frequency								
252		Mechanical & Electropolish	167	80	2.0	Extruded	L.E.V.	β M	.1784* 57.83	.2759* 37.39	.3742 27.57	.4267 24.18	.5787 17.82	.6598 15.63	.8949* 11.52	1.020* 10.11	1.578* 6.537
253		Mechanical & Electropolish	50	80	2.0	Extruded	Weibull	b θ X_o	1.534* 48.66 41.14	1.534* 35.94 30.39	1.534 29.08 24.59	1.534 26.54 22.44	1.711 21.49 17.98	1.619 19.61 16.50	1.729 15.87 13.26	1.662 14.49 12.15	1.768* 10.70 8.923
254		Mechanical & Electropolish	20	80	2.0	Extruded	Weibull	b θ X_o	1.509* 50.37 33.84	1.507* 34.95 23.26	1.578 27.06 17.99	1.578 24.23 16.11	1.471 18.73 12.65	1.425 16.77 11.40	1.475 12.99 8.771	1.443 11.63 7.887	1.497 8.068 5.430
									Effect of Manufacturing Processes								
255		Mechanical and Electropolish	50	80	1.0	Extrusions	Normal	σ μ	7.953* 67.01	6.175* 52.03	5.175* 43.60	4.795 40.40	4.018 33.85	3.723 31.37	3.120 26.28	2.891 24.36	2.245* 18.91
256		Mechanical and Electropolish	50	80	1.0	Forged	Weibull	b θ X_o	5.009* 72.62 42.75	4.775* 57.48 34.69	4.772 48.81 29.47	4.918 45.50 27.05	4.806 38.64 23.25	4.764 36.01 21.76	4.874 30.59 18.27	4.841 28.51 17.09	4.743* 22.56 13.66
257				80	1.0	Wrought	Weibull	b θ X_o		3.089 77.04 55.45	3.077 68.13 49.10	3.077 64.62 46.57	3.077 57.16 41.19	3.077 54.21 39.07	3.037 47.95 34.67	3.211 45.49 32.39	3.085* 38.15 27.47

S_u = 71-87 ksi
S_y = 67-69 ksi

7075 ALUMINUM (Cont'd)
(EXTRUSIONS AND FORGINGS)

Composition: See Page 167
(*) Extrapolated Values

†Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING Effect of Stress Concentration								
258		Mechanical and Electropolishing	167	80	1.0	Extrusions	Weibull	b	1.466*	1.561*	1.506	1.526	1.568	1.585	1.618	1.631	1.669*
								θ	53.04	44.98	40.04	38.10	33.95	32.30	28.78	27.38	23.21
								X_o	38.19	32.05	28.71	27.26	24.17	22.95	20.36	19.34	16.31
259			167	80	2.0		L.E.V.	β	.1784*	.2759*	.3742	.4267	.5787	.6598	.8949*	1.020*	1.578*
								M	57.83	37.39	27.57	24.18	17.82	15.63	11.52	10.11	6.537
260			50	80	1.0		Normal	σ	7.953*	6.175*	5.175*	4.795	4.018	3.723	3.120	2.891	2.245*
								μ	67.01	52.03	43.60	40.40	33.85	31.37	26.28	24.36	18.91
261			50	80	2.0		Weibull	b	1.534*	1.534*	1.534	1.534	1.711	1.619	1.729	1.662	1.768*
								θ	48.66	35.94	29.08	26.54	21.49	19.61	15.87	14.49	10.70
								X_o	41.14	30.39	24.59	22.44	17.98	16.50	13.26	12.15	8.923
262			20	80	1.0		Normal	σ	7.743*	6.515*	5.775	5.482	4.859	4.613	4.088	3.881	3.266*
								μ	48.19	40.55	35.94	34.12	30.24	28.71	25.44	24.16	20.32
263			20	80	2.0		Weibull	b	1.509*	1.507*	1.578	1.578	1.471	1.425	1.475	1.443	1.497*
								θ	50.37	34.95	27.06	24.23	18.73	16.77	12.99	11.63	8.068
								X_o	33.84	23.26	17.99	16.11	12.65	11.40	8.771	7.887	5.430

S_u = 78 ksi
S_y = 76 ksi

7075 ALCLAD ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									PLATE BENDING (Completely Reversed) Miscellaneous								
264	T-6		20	80	1.0	Hot Rolled	Weibull	b θ X_o	1.909* 43.48 35.88	1.750* 33.67 28.04	1.977* 28.19 23.17	1.945 26.11 21.49	1.879 21.84 18.05	1.853 20.22 16.74	1.845 16.92 14.01	1.845 15.67 12.98	1.845* 12.14 10.05
									AXIAL (Completely Reversed) Miscellaneous								
265	T-6	Milled Edges	20	80	1.0	Cold Rolled	L.E.V.	β M	.2339* 70.71	.3744 44.17	.5202 31.79	.5994 27.59	.8328 19.86	.9586 17.23	1.333* 12.40	1.536* 10.76	2.459* 6.726
266	T-6	Milled Edges	20	80	2.5		Weibull	b θ X_o	3.986* 41.72 32.15	3.695 26.89 21.08	3.886 19.79 15.34	3.839 17.34 13.48	3.829* 12.76 9.928	3.829* 11.18 8.700	2.829* 8.230 6.402	3.829* 7.211 5.609	3.829* 4.650 3.617

S_u = 81 ksi
S_y = 64 ksi

7076 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING — Effect of Frequency																
267	HT-9	Mechanical Polish 1 RMS	100	80	1.0	Forged and Swaged	S.E.V.	β M	.4940* 61.21	.6051* 49.97	.6972* 43.37	.7411* 40.80	.8540 35.41	.9077 33.31	1.045 28.91	1.111 27.20	1.361* 22.21
268	HT-9	Mechanical Polish 1 RMS	167	80	1.0	Forged and Swaged	S.E.V.	β M	.5746* 42.86	.6522* 37.76	.7126* 34.56	.7403* 33.27	.8088* 30.45	.8403 29.31	.9181 26.83	.9538 25.82	1.082* 22.75
269	HT-9	Mechanical Polish 1 RMS	200	80	1.0	Forged and Swaged	Weibull	b θ X_o	2.810* 41.45 35.29	2.759* 37.67 32.14	2.726* 35.24 30.10	2.712* 34.24 29.26	2.682* 32.02 27.41	2.681 31.11 26.63	2.681 29.10 24.91	2.681 28.28 24.20	2.681* 25.70 22.00
	Miscellaneous																
270		M.P. 4 RMS	167	80	1.0	Forged and Swaged	Weibull	b θ X_o	2.468* 67.52 58.09	2.283 51.78 44.88	2.336 43.03 37.21	2.249 39.72 34.47	2.499 33.01 28.36	2.329 30.47 26.36	2.386 25.32 21.85	2.503* 23.38 20.08	2.321* 17.93 15.51
271	HT-9	M.P. 1 RMS	100	80	3.4	Forged and Swaged	L.E.V.	β M	.1809* 23.44	.2181* 19.44	.2486* 17.06	.2630* 16.13	.2997 14.15	.3170 13.38	.3613 11.74	.3822 11.10	.4608* 9.208

HT-9: Aged 560°F, 10 hrs, W.Q., Aged 275°F, 12 hrs, A.C.

S_u = 81 ksi
S_y = 64 ksi

7076 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
272	HT-9	M.P.	25	80	1.0	Forged and Swaged	Weibull	b θ X_o	1.763* 45.48 31.24	1.797* 38.37 26.23	1.818* 34.07 23.22	1.826* 32.37 22.04	1.707 28.70 19.87	1.712 27.26 18.86	1.712 24.20 16.75	1.712 22.99 15.91	1.712* 19.39 13.42
273	HT-9	As is	29	80	2.2	Forged and Swaged	Normal	σ μ	3.354* 25.62	3.051* 23.31	2.855* 21.81	2.775* 21.20	2.597 19.84	2.524 19.28	2.362 18.05	2.296 17.54	2.088* 15.96

S_u = 61 ksi
S_y = 55 ksi

7106 ALUMINUM

Composition: See Page
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
274	T-6	M.P.		80	1.0	Hot Rolled	Normal	σ μ	3.820* 56.87	2.353 35.02	1.677 24.96	1.449 21.57	1.032 15.37	.8927* 13.28	.6362* 9.470	.5498* 8.184	.3386* 5.041

S_u = 70-79 ksi
S_y = 63-66 ksi

7079 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Direction of Loading																
275	T-6			80	1.0	Longi-tudinal	L.E.V.	β M	.3172* 51.12	.3698* 43.84	.4117* 39.38	.4312* 37.60	.4800 33.77	.5027 32.25	.5597 28.97	.5861 27.66	.6834* 23.72
276	T-6			80	1.0	Long Transv.	S.F.V.	β M	.3824* 51.86	.4455* 44.51	.4958* 40.00	.5191 38.20	.5776 34.33	.6048 32.79	.6730 29.47	.7046 28.14	.8210* 24.16
277	T-6			80	1.0	Short Transv.	L.E.V.	β M	.2804* 40.16	.3167* 35.56	.3448* 32.66	.3576 31.49	.3893 28.92	.4038 27.88	.4397 25.61	.4561 24.69	.5150 21.86
278	T-6			80	Notched	Longi-tudinal	Weibull	b θ X_o	1.637* 34.33 30.95	1.821* 25.99 23.24	1.711* 21.37 19.21	1.669 19.65 17.69	1.637 16.17 14.57	1.637 14.86 13.40	1.637* 12.23 11.02	1.857* 11.25 10.05	1.857* 8.514 7.604
279	T-6			80	Notched	Long Transv.	Weibull	b θ X_o	.9525* 31.89 27.60	.9525* 25.66 22.20	.9525* 22.04 19.07	.9525* 20.64 17.86	.9525 17.73 15.34	.9525 16.61 14.37	.9153 14.26 12.37	.8435 13.34 11.64	.9286* 10.75 9.320
280	T-6			80	Notched	Short Transv.	Weibull	b θ X_o	1.053* 24.91 21.26	.8126* 21.08 18.31	.8709* 18.84 16.30	.8721 17.94 15.53	.7569 15.99 13.93	1.042 15.31 13.08	.9394 13.64 11.75	.8936 12.98 11.21	1.065* 11.07 9.446

S_u = 70-71 ksi
S_y = 63-66 ksi

7079 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp°F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
281	T-6			80	1.0	Longitudinal	L.E.V.	β M	.3172* 51.12	.3698* 43.84	.4117* 39.38	.4312* 37.60	.4800 33.77	.5027 32.25	.5597 28.97	.5861 27.66	.6834* 23.72
282	T-6			80	Notch	Longitudinal	Weibull	b θ X_o	1.637* 34.33 30.95	1.821* 25.99 23.24	1.711* 21.37 19.21	1.669 19.65 17.69	1.637 16.17 14.57	1.637 14.86 13.40	1.637* 12.23 11.02	1.857* 11.25 10.05	1.857* 8.514 7.604
283	T-6			80	1.0	Long Transverse	S.E.V.	β M	.3824* 51.86	.4455* 44.51	.4958* 40.00	.5191 38.20	.5776 34.33	.6048 32.79	.6730 29.47	.7046 28.14	.8210* 24.16
284	T-6			80	Notch	Long Transverse	Weibull	b θ X_o	.9525* 31.89 27.60	.9525* 25.66 22.20	.9525* 22.04 19.07	.9525* 20.64 17.86	.9525 17.73 15.34	.9525 16.61 14.37	.9153 14.26 12.37	.8435 13.34 11.64	.9286* 10.75 9.320
285	T-6			80	1.0	Short Transverse	L.E.V.	β M	.2804* 40.16	.3167* 35.56	.3448* 32.66	.3576 31.49	.3893 28.92	.4038 27.88	.4397 25.61	.4561 24.69	.5150 21.86
286	T-6			80	Notch	Short Transverse	Weibull	b θ X_o	1.053* 24.91 21.26	.8126* 21.08 18.31	.8709* 18.84 16.30	.8721 17.94 15.53	.7569 15.99 13.93	1.042 15.31 13.08	.9394 13.64 11.75	.8936 12.98 11.21	1.065* 11.07 9.446

S_u = 70-79 ksi
S_y = 63-66 ksi

7079 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING Miscellaneous																
287	T-6			80	1.0		S.E.V.	β M	.2739* 42.36	.3010* 38.54	.3216 36.08	.3308 35.07	.3534 32.83	.3636 31.91	.3884 29.87	.3996 29.04	.4391* 26.42
288	T-652	M.P. 16 RMS		80	1.0	Forged	Weibull	b θ X_o	3.113* 63.26 44.73	3.040 48.75 34.71	3.059 40.63 28.88	3.218 37.58 26.30	3.130 31.32 22.11	3.096 28.96 20.51	3.230 24.14 16.87	3.204* 22.32 15.64	3.132* 17.20 12.14
	AXIAL (Completely Reversed) Miscellaneous																
289	T-6	M.P. 10 RMS		80	1.0	Drawn	Normal	σ μ	6.466* 43.50	5.555 37.37	4.995 33.60	4.772 32.10	4.291 28.87	4.099 27.58	3.686 24.80	3.521 23.69	3.025* 20.35
290	T-652	M.P. 8 RMS		80	1.0	Forged	Weibull	b θ X_o		4.665 45.70 25.09	4.502 31.10 17.47	4.355 26.35 15.11	4.065 17.93 10.69	3.999* 15.19 9.139	3.882* 10.34 6.314	3.844* 8.764 5.376	3.806* 5.055 3.116

S_u = 88 ksi
S_y = 78 ksi

7178 ALUMINUM

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Grain Direction																
291	T-6			80	1.0	Longi-tudinal	S.E.V.	β M	.2237* 84.07	.2840* 66.22	.3355 56.05	.3605 52.16	.4260 44.15	.4577 41.08	.5408 34.77	.5811 32.36	.7378 25.49
292	T-6			80	1.0	Long Transv.	Weibull	b θ X_o		6.116* 69.68 50.06	5.738 59.35 43.53	6.116 55.39 39.80	6.013 47.18 34.09	5.919 44.03 31.98	5.864 37.51 27.32	5.978 35.01 25.34	5.684 27.83 20.47
293	T-6			80	Notched	Longi-tudinal	L.E.V.	β M	.1465* 39.74	.1901* 30.62	.2281 25.52	.2467 23.60	.2960 19.67	.3202 18.18	.3842 15.15	.4155 14.01	.5393 10.79
294	T-6			80	Notched	Long Transv.	Weibull	b θ X_o	3.177* 37.78 27.22	3.067* 29.22 21.26	3.220 24.42 17.53	3.197 22.61 16.26	3.149 18.89 13.64	3.131 17.48 12.65	3.121 14.61 10.58	3.121 13.52 9.796	3.121* 10.46 7.578

S_u = 88 ksi
S_y = 78 ksi

7178 ALUMINUM (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
							ROTARY BEAM BENDING — Effect of Stress Concentration										
295	T-6			80	1.0	Longitudinal	S.E.V.	β M	.2237* 84.07	.2840* 66.22	.3355 56.05	.3605 52.16	.4260 44.15	.4577 41.08	.5408 34.77	.5811 32.36	.7378 25.49
296	T-6			80	Notch	Longitudinal	L.E.V.	β M	.1465* 39.74	.1901* 30.62	.2281 25.52	.2467 23.60	.2960 19.67	.3202 18.18	.3842 15.15	.4155 14.01	.5393 10.79
297	T-6			80	1.0	Long Transverse	Weibull	b Θ X_o		6.116* 69.68 50.06	5.738 59.35 43.53	6.116 55.39 39.80	6.013 47.18 34.09	5.919 44.03 31.98	5.864 37.51 27.32	5.978 35.01 25.34	5.684 27.83 20.47
298	T-6			80	Notch	Long Transverse	Weibull	b Θ X_o	3.177* 37.78 27.22	3.067* 29.22 21.26	3.220 24.42 17.53	3.197 22.61 16.26	3.149 18.89 13.64	3.131 17.48 12.65	3.121 14.61 10.58	3.121 13.52 9.796	3.121* 10.46 7.578

A-1.5.2 Cobalt Alloys

S_u = 123 ksi
S_y = 65 ksi

STELLITE - 31

Composition: See Page 167
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	ROTARY BEAM BENDING — Effect of Test Temperature																
299	1400°F, 16 hrs., FC Cast	Mechanical Polish		1200	1.0		S.E.V.	β	.1827*	.2256	.2615	.2787	.3229*	.3441*	.3988*	.4250*	.5248*
								M	77.80	63.00	54.36	51.01	44.02	41.31	35.64	33.45	27.08
300	1400°F, 16 hrs., FC Cast	Mechanical Polish		1350	1.0		Weibull	b	1.052*	.7867	1.439	.7676*	.9330*	.8038*	1.335*	1.250*	.9850*
								θ	68.56	53.68	45.44	42.09	35.55	33.01	27.93	25.95	20.32
								X_o	65.19	51.37	42.73	40.30	33.90	31.58	26.35	24.54	19.36
301	1400°F, 16 hrs., FC Cast	Mechanical Polish		1500	1.0		Weibull	b	1.642*	1.492	1.478	1.394*	1.507*	1.456*	1.642*	1.642*	1.642*
								θ	72.94	45.33	32.53	28.18	20.24	17.54	12.60	10.92	6.797
								X_o	61.44	38.62	27.74	24.17	17.22	14.98	10.61	9.202	5.725
	AXIAL (Completely Reversed) — Effect of Stress Concentration																
302	1300°F, 50 hrs., AC Cast	M.P. 10 RMS	60	80	1.0		Normal	σ	5.843*	5.122	4.671	4.489	4.095	3.935	3.589	3.450	3.024*
								μ	75.81	66.45	60.61	58.25	53.13	51.06	46.57	44.76	39.24
303	1300°F, 50 hrs., AC Cast	Ground 10 RMS	60	80	2.4		Normal	σ	7.838*	6.101*	5.120*	4.748*	3.985	3.696	3.102	2.877	2.239*
								μ	65.24	50.78	42.62	39.53	33.17	30.76	25.82	23.94	18.64
304	1300°F, 50 hrs., AC Cast	Ground 10 RMS	60	80	3.4		Weibull	b	1.037*	1.048*	1.055*	1.057*	1.064	1.067	1.073	1.076*	1.084*
								θ	31.85	30.84	30.15	29.86	29.19	28.91	28.26	27.99	27.10
								X_o	26.44	25.57	24.99	24.74	24.17	23.93	23.38	23.15	22.39

S_u = 123 ksi
S_y = 65 ksi

STELLITE - 31 (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
305	1300 °F, 50 hrs., AC, Cast	M.P. 10 RMS	60	1200	1.0		Weibull	b	2.668*	2.668*	2.668	2.668	2.668	2.668	2.668*	2.668*	2.640*
								θ	45.61	44.21	43.26	42.86	41.94	41.55	40.66	40.28	39.05
								X_o	39.86	38.64	37.81	37.46	36.65	36.31	35.53	35.20	34.16
306		Ground 10 RMS	60	1200	3.4		L.E.V.	β	.5549*	.5984*	.6308*	.6453*	.6803	.6959*	.7336*	.7505*	.8093*
								M	29.13	27.01	25.62	25.04	23.76	23.22	22.03	21.54	19.97
307		M.P. 10 RMS	60	1500	1.0		S.E.V.	β	.9139*	.9582*	.9905	1.004	1.038	1.053	1.089	1.104*	1.158*
								M	37.09	35.37	34.22	33.73	32.63	32.17	31.12	30.68	29.26
308		Ground - 10 RMS	60	1500	2.4		Weibull	b	.9818*	1.406*	1.344*	1.302	1.205	1.164	1.065	1.022	.8630*
								θ	31.80	28.84	26.89	26.09	24.31	23.59	21.98	21.33	19.28
								X_o	29.84	26.70	24.94	24.23	22.66	22.02	20.58	19.99	18.15
309			60	1500	3.4		Weibull	b	4.108*	3.791*	4.065	3.767	4.042	4.035*	4.020*	4.014*	3.704*
								θ	26.71	24.98	23.85	23.37	22.31	21.87	20.88	20.46	19.14
								X_o	19.93	19.06	17.85	17.86	16.73	16.40	15.67	15.37	14.69

S_u = 123 ksi
S_y = 65 ksi

STELLITE - 31 (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
310	1300°F, 50 hrs., AC, Cast	M.P. 10 RMS	60	80	1.0		Normal	σ μ	5.843* 75.81	5.122 66.45	4.671 60.61	4.489 58.25	4.095 53.13	3.935 51.06	3.589 46.57	3.450 44.76	3.024* 39.24
311	1300°F, 50 hrs., AC, Cast	M.P. 10 RMS	50	1200	1.0		Weibull	b θ X_o	2.668* 45.61 39.86	2.668* 44.21 38.64	2.668 43.26 37.81	2.668 42.86 37.46	2.668 41.94 36.65	2.668 41.55 36.31	2.668* 40.66 35.53	2.668* 40.28 35.20	2.640* 39.05 34.16
312	1300°F, 50 hrs., AC, Cast	M.P. 10 RMS	60	1500	1.0		S.E.V.	β M	.9139* 37.09	.9582* 35.37	.9905 34.22	1.004 33.73	1.038 32.63	1.053 32.17	1.089 31.12	1.104* 30.68	1.158* 29.26
313	1300°F, 50 hrs., AC, Cast	Ground - 10 RMS	60	80	2.4		Normal	σ μ	7.838* 65.24	6.101* 50.78	5.120* 42.62	4.748* 39.53	3.985 33.17	3.696 30.76	3.102 25.82	2.877 23.94	2.239* 18.64
314	1300°F, 50 hrs., AC, Cast	Ground - 10 RMS	60	1500	2.4		Weibull	b θ X_o	.9818* 31.80 29.84	1.406* 28.84 26.70	1.344* 26.89 24.94	1.302 26.09 24.23	1.205 24.31 22.66	1.164 23.59 22.02	1.065 21.98 20.58	1.022 21.33 19.99	.8630* 19.28 18.15

S_u = 123 ksi
S_y = 65 ksi

STELLITE - 31 (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
315	1300°F, 50 hrs., AC,	Ground - 10 RMS	60	80	3.4	Cast	Weibull	b	1.037*	1.048*	1.055*	1.057*	1.064	1.067	1.073	1.076*	1.084*
								θ	31.85	30.84	30.15	29.86	29.19	28.91	28.26	27.99	27.10
								X_o	26.44	25.57	24.99	24.74	24.17	23.93	23.38	23.15	22.39
316			60	1200	3.4		L.E.V.	β	.5549*	.5984*	.6308*	.6453*	.6803	.6959*	.7336*	.7505*	.8093*
								M	29.13	27.01	25.62	25.04	23.76	23.22	22.03	21.54	19.97
317			60	1500	3.4		Weibull	b	4.108*	3.791*	4.065	3.767	4.042	4.035*	4.020*	4.014*	3.704*
								θ	26.71	24.98	23.85	23.37	22.31	21.87	20.88	20.46	19.14
								X_o	19.93	19.06	17.85	17.86	16.73	16.40	15.67	15.37	14.69

S_u = 148 ksi
S_y = 74-76 ksi

S-816

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING Miscellaneous								
318	HT-10	M.P. 10 RMS	60	1500	1.0		Weibull	b θ X_o	.7800 66.11 56.90	.7800 57.01 49.07	.7800 51.40 44.24	.7800 49.16 42.31	.7800 44.32 38.15	.7800 42.39 36.48	.7800 38.22 32.90	.7800* 36.55 31.46	.7800* 31.52 27.13
319	HT-11			1200	1.0		Weibull	b θ X_o	5.119* 78.64 58.85	5.118 75.83 56.75	5.119 73.92 55.32	5.119 73.12 54.72	5.119 71.28 53.34	5.119 70.50 52.76	5.119 68.73 51.44	5.119* 67.98 50.88	5.119* 65.55 49.06
									PLATE BENDING (Completely Reversed) Miscellaneous								
320	HT-12	Ground 5 RMS	60	1500	1.0		L.E.V.	β M	1.059* 60.95	1.168* 55.28	1.250* 51.63	1.287* 50.14	1.378 46.83	1.420 45.47	1.520 42.47	1.565 41.24	1.726* 37.40
321	HT-12	Rough 75 RMS	60	1200	1.0		L.E.V.	β M	.0528* 56.64	.0563* 53.13	.0589* 50.81	.0601* 49.84	.0628 47.66	.0640 46.75	.0670 44.71	.0683 43.85	.0728* 41.13

HT-10: Sol. H.T. - 2300 °F - 1 hr, W.Q.; Aged 1400°F, 16 hrs, F.C.
HT-11: Sol. H.T. - 2100°F, Forged, 2150°F, 1 hr, W.Q. 1500°F, 5 hrs, AC
HT-12: Sol. H.T. - 2150 °F, 1 hr, W.Q.; Aged 1400°F, 16 hrs, AC.

S_u = 147-148 ksi
S_y = 74-76 ksi

S-816 (Cont'd)

Composition: See Page 167
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

TEST CONDITIONS							FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp. °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
322	HT-10	Mechanical Polishing or Ground - 10 RMS	60	80	1.0	Hot Rolled	Weibull	b	3.239*	3.524	3.425	3.384	3.292	3.252	3.166	3.568	3.456*
								θ	74.55	70.99	68.59	67.59	65.30	64.34	62.17	61.28	58.34
								X_c	63.38	59.64	57.86	57.11	55.40	54.67	53.02	51.38	49.15
323	HT-10		60	80	2.4		Weibull	b	2.095*	2.003*	2.093*	2.026*	2.159	2.110	2.008	1.970	2.136*
								θ	100.2	75.12	61.41	56.29	46.02	42.19	34.47	31.59	23.68
								X_o	83.22	62.73	50.96	46.93	38.01	34.97	28.77	26.44	19.59
324	HT-10		60	1500	1.0		Weibull	b	1.168*	1.081*	1.015	.9858	.9123	.8777	.7876	.7422	1.080*
								θ	42.63	41.46	40.65	40.31	39.53	39.19	38.43	38.10	37.14
								X_o	41.17	40.12	39.39	39.09	38.38	38.08	37.40	37.10	35.94
325	HT-10		60	1500	2.4		Weibull	b	1.315*	.9385	.8534	.9587	1.044	1.073	1.132*	1.147*	.8574*
								θ	35.76	30.49	27.37	26.18	23.57	22.53	20.27	19.37	16.55
								X_o	29.80	26.23	23.67	22.50	20.13	19.19	17.18	16.40	14.30
326	HT-10		60	1650	1.0		L.E.V.	β	.7158*	.8067*	.8770*	.9092*	.9884*	1.024	1.114	1.154	1.301*
								M	46.68	41.42	38.10	36.75	33.80	32.61	29.99	28.93	25.67
327	HT-10		60	1650	3.4		Weibull	b	1.110*	1.029*	.9697	.9431	1.465	1.469	1.433	1.418	1.366*
								θ	25.86	24.28	23.23	22.80	21.88	21.47	20.54	20.16	18.93
								X_o	24.01	22.60	21.66	21.27	20.04	19.67	18.85	18.51	17.41

A-1.5.3 Copper Alloys

S_u = 32-36 ksi
S_y = 7.5- 13 ksi

PURE COPPER

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
									PLATE BENDING (Completely Reversed) Miscellaneous								
328				80	1.0		Weibull	b	4.385*	4.446*	4.374	4.345	4.285	4.261	4.210	4.190*	4.132*
								θ	15.03	12.49	10.97	10.38	9.125	8.631	7.585	7.174	5.963
								X_o	9.900	8.180	7.240	6.868	6.071	5.756	5.083	4.817	4.027
329				80	1.0	Cold Worked	L.E.V.	β		.4431	.5691	.6339*	.8142*	.9069*	1.164*	1.297*	1.856*
								M		35.78	27.86	25.01	19.47	17.48	13.61	12.22	8.544
									AXIAL (Completely Reversed) Miscellaneous								
330	Annealed			80	1.0		Weibull	b	1.659*	1.743*	1.743*	1.743*	1.743	1.743	1.743*	1.743*	1.743*
								θ	34.04	24.15	19.00	17.13	13.48	12.15	9.565	8.626	6.119
								X_o	30.82	21.80	17.15	15.46	12.16	10.97	8.631	7.784	5.522
									Effect of Stress Concentration								
331	HT-14		1470	482	1.0		Weibull	b	8.378*	7.548*	7.095	7.579	7.242	7.769	7.671	7.634	8.169*
								θ	27.49	23.47	21.01	20.04	17.94	17.11	15.32	14.61	12.47
								X_o	21.35	18.70	16.97	15.95	14.42	13.54	12.16	11.61	9.753
332	HT-14		1470	482	No-N		Weibull	b	4.248*	4.111*	4.357*	4.004	4.275	4.275	3.951	3.951	4.275
								θ	21.30	16.59	13.94	12.92	10.86	10.07	8.458	7.845	6.113
								X_o	16.22	12.75	10.54	9.997	8.257	7.659	6.561	6.086	4.648

HT-14: Annealed at 752 °F, F.C.

S_u = 42-55 ksi
S_y = 8.7-23 ksi

<u>70-30 BRASS</u>

Composition: See Page 167
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Grain Size																
333	Cold Rolled and Annealed	Electropolished		80	1.0	.016mm grain	S.E.V.	β M				1.062* 28.61	1.189* 25.56	1.248* 24.35	1.396 21.76	1.466* 20.73	1.722* 17.65
334	Cold Rolled and Annealed	Electropolished		80	1.0	.022mm grain	Weibull	b θ X_o			9.184* 27.77 24.10	10.40* 26.30 22.40	9.184* 23.17 20.11	9.185 21.94 19.04	9.184 19.32 16.77	9.795 18.30 15.73	7.961* 15.26 13.49
335	Extruded and Annealed	Electropolished		80	1.0	.033mm grain	Weibull	b θ X_o				2.586* 20.54 19.41	2.586* 19.02 17.97	2.586* 18.40 17.39	2.586 17.03 16.10	2.586 16.48 15.57	2.586* 14.76 13.95
336	Extruded and Annealed	Electropolished		80	1.0	.04mm grain	S.E.V.	β M			2.593* 21.77	2.709* 20.84	2.997 18.84	3.130 18.04	3.463 16.30	3.617 15.61	4.179* 13.51
337	Extruded and Annealed	Electropolished		80	1.0	.075mm grain	Weibull	b θ X_o				1.222* 22.35 21.80	1.637* 19.33 18.76	1.637* 18.15 17.62	1.637 15.69 15.23	1.439 14.73 14.33	1.637* 11.96 11.61
338	Extruded and Annealed	Electropolished		80	1.0	.33mm grain	Weibull	b θ X_o				1.575* 14.02 12.92	1.575* 12.83 11.82	1.575* 12.35 11.38	1.575 11.30 10.41	1.575 10.87 10.02	1.575* 9.576 8.827

S_u = 42-55 ksi
S_y = 8.7-23 ksi

<u>70-30 BRASS (Cont'd)</u>

Composition: See Page 167
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Stress Concentration																
339	Cold Rolled and Annealed	Electropolished		80	1.0	Grain Size .016 mm	S.E.V.	β M				1.062* 28.61	1.189* 25.56	1.248* 24.35	1.396 21.76	1.466* 20.73	1.722* 17.65
340	Cold Rolled and Annealed	Electropolished		80	Sharp-N	Grain Size .016 mm	S.E.V.	β M				1.267* 19.05	1.766* 13.67	2.038* 11.85	2.840 8.503	3.277* 7.371	5.269* 4.584
341	Extruded and Annealed	Electropolished		80	1.0	Grain Size = 0.033 mm	Weibull	b θ X_o				2.586* 20.54 19.41	2.586* 19.02 17.97	2.586* 18.40 17.39	2.586 17.03 16.10	2.586 16.48 15.57	2.586* 14.76 13.95
342	Extruded and Annealed	Electropolished		80	Sharp-N	Grain Size = 0.033 mm	S.E.V.	β M			1.418* 22.53	1.609* 19.86	2.155* 14.83	2.445 13.07	3.276 9.760	3.715* 8.605	5.645* 5.663
343	Extruded and Annealed	Electropolished		80	K_t-1	Grain Size = 0.033 mm	S.E.V.	β M				1.753* 18.67	1.984* 16.50	2.093* 15.64	2.368 13.82	2.498 13.10	2.981 10.98
344	Extruded and Annealed	Electropolished		80	K_t-2	Grain Size = 0.033 mm	Weibull	b θ X_o				2.149* 17.67 14.76	2.149* 14.76 12.33	2.149 13.66 11.41	2.149 11.41 9.536	2.149 10.56 8.825	2.149* 8.167 6.822

K_t-1: Cracked, cracks .11-.14 mm deep
K_t-2: Cracked, cracks .27-.34 mm deep

S_u = 42-72 ksi
S_y = 10-35 ksi

Cu-7.3 Al BRONZE

Composition: See Page 168
(*) Extrapolated Values

CANTILEVER BEAM BENDING (Completely Reversed)
Effect of Grain Size

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
345				80	1.0	.2-.5 mm gr.	Weibull	b	.8827*	1.004*	1.028	1.029	.9475	.8956	.7649*	.6983*	.9717*
								θ	27.05	22.69	20.05	19.00	16.75	15.86	13.97	13.23	11.13
								X_o	24.26	20.18	17.80	16.87	14.96	14.21	12.62	11.98	9.925
346				80	1.0	.022mm grain	Weibull	b		3.429*	3.481	3.256	3.611	3.456	3.558*	3.507*	3.360*
								θ		57.01	48.56	45.31	38.60	36.01	30.67	28.62	22.75
								X_o		47.24	40.14	37.85	31.71	29.80	25.26	23.63	18.91

S_u = 60 ksi
S_y = 19 ksi

5.6 Al BRONZE

Composition: See Page 168
(*) Extrapolated Values

CANTILEVER BEAM BENDING
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
347				80	1.0	.042mm grain	S.E.V.	β	1.540*	1.798*	2.004	2.099	2.340	2.451	2.732*	2.862*	3.342*
								M	38.83	33.25	29.84	28.48	25.56	24.39	21.89	20.89	17.89

Al-Ni BRONZE

S_u = 116 ksi
S_y = 85 ksi

Composition: See Page 168
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$

ROTARY BEAM BENDING
Miscellaneous

348		M.P.		80	1.0		Weibull	b θ X_o				2.037* 66.26 58.68	2.006* 60.55 53.68	1.978* 58.24 51.69	1.915 53.22 47.33	1.890 51.19 45.57	1.807* 45.00 40.16

PHOSPHOR BRONZE

S_u = 47 ksi
S_y = 14 ksi

Composition: See Page 168
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Miscellaneous

349	1 hr. at 500°C			80	V-Not.		L.E.V.	β M			.2364* 12.22	.2611* 11.06	.3289* 8.786	.3633 7.955	.4576 6.315	.5054* 5.717	.7032* 4.109

S_u = 48.5 ksi
S_y = 13.3 ksi

MUNTZ METAL (BRASS)

Composition: See Page 168
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									PLATE BENDING (Completely Reversed) Miscellaneous								
350	1 hr. at 550°C			80	V-Not.		S.E.V.	β M				.4722* 12.94	.5726* 10.67	.6222* 9.820	.7546 8.098	.8200 7.452	1.080* 5.655

S_u = 76.6 ksi
S_y = 32.8 ksi

Cu-6.5 Al-2.4 Fe

Composition: See Page 168
(*) Extrapolated Values

CANTILEVER BEAM BENDING
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
351				80	1.0	.0075 mm gr.	S.E.V.	β M	.4006* 63.81	.4774* 53.54	.5397 47.37	.5689 44.93	.6431 39.75	.6780 37.70	.7664 33.35	.8080* 31.64	.9628* 26.55

A-1.5.4 Magnesium Alloys

2.5 Al MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
352		Electropolished		80	1.0		Normal	σ μ	2.273* 13.35	1.892* 11.11	1.664* 9.778	1.575 9.252	1.385 8.139	1.311 7.702	1.153 6.775	1.091 6.412	.9086* 5.337
353		Electropolished		80	2.6		S.E.V.	β M	.4714* 15.77	.7141* 10.41	.9546* 7.791	1.081* 6.875	1.446 5.143	1.638 4.539	2.190 3.395	2.482 2.996	3.760* 1.978
354		Electropolished		80	2.8		S.E.V.	β M	.3895* 22.79	.6559* 13.53	.9442* 9.403	1.104* 8.038	1.589 5.584	1.860 4.773	2.677 3.316	3.132 2.834	5.274* 1.683
355		Electropolished		80	3.8		Normal	σ μ	1.120* 7.760	.8964* 6.206	.7668* 5.309	.7170* 4.964	.6133 4.246	.5734 3.970	.4905 3.396	.4586 3.175	.3668* 2.540
356		Electropolished		80	4.3		S.E.V.	β M	.3786* 20.19	.6273* 12.18	.8930* 8.561	1.039* 7.354	1.479* 5.166	1.722 4.437	2.452 3.116	2.854 2.678	4.730* 1.616
357		Electropolished		80	6.5		Weibull	b θ X_o	2.364* 7.660 5.528	2.364* 5.918 4.271	2.364* 4.941 3.566	2.364* 4.572 3.299	2.364 3.818 2.755	2.364 3.532 2.549	2.364 2.949 2.128	2.364 2.729 1.969	2.364* 2.108 1.521

S_u = 37 ksi
S_y = 22 ksi

AZ31A MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
358	HT-15	M.P. & E.P.		80	1.0		Weibull	b	5.977*	5.664*	6.037*	5.962	5.813	5.785	5.724	5.698*	6.181*
								θ	19.25	17.53	16.42	15.96	14.95	14.53	13.61	13.23	12.05
								X_o	15.59	14.34	13.26	12.93	12.17	11.84	11.12	10.82	9.691

AZ31B MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Environment

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
359	HT-15	Mechanical Polishing		80	1.0	in Air	Weibull	b	5.116*	4.936*	4.851	4.818	4.749	4.722	4.665	4.643	4.578*
								θ	26.89	21.97	19.07	17.95	15.58	14.66	12.73	11.98	9.792
								X_o	17.51	14.53	12.71	11.99	10.48	9.884	8.624	8.130	6.679
360	HT-15	Mechanical Polishing		80	1.0	in Sea Water	Weibull	b	1.427*	1.297	1.217*	1.103*	1.103*				
								θ	43.61	16.59	8.449	6.316	3.217				
								X_o	37.19	14.27	7.301	5.486	2.794				

HT-15: Stress relieved at 500°F, 15 min, A.C.

S_u = 45-46 ksi
S_y = 29-34 ksi

AZ61A MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Stress Concentration																
361		M.P.	25	80	1.0		Weibull	b	1.735*	1.832	1.789	1.718	1.832	1.818*	1.712*	1.832*	1.832*
								θ	42.57	31.82	25.95	23.76	19.39	17.76	14.48	13.27	9.920
								X_o	35.77	26.57	21.73	19.99	16.20	14.85	12.19	11.08	8.285
362		ground	25	80	3.9		Weibull	b	3.374*	3.374*	3.305	3.277	3.219	3.198	3.155	3.140	3.097*
								θ	19.81	14.46	11.60	10.55	8.473	7.707	6.185	5.626	4.107
								X_o	8.915	6.509	5.317	4.871	3.966	3.626	2.941	2.685	1.980
	PLATE BENDING (Completely Reversed) — Effect of Frequency																
363	HT-16	Mechanical Polishing	29	80	1.0		Normal	σ	4.008*	3.395*	3.023*	2.876	2.561	2.436	2.169	2.063	1.747*
								μ	23.11	19.57	17.43	16.58	14.76	14.04	12.50	11.89	10.07
364	HT-16	Mechanical Polishing	167	80	1.0		Weibull	b	5.400*	5.400*	5.400	5.381	5.574	5.421	5.494	5.367	5.393*
								θ	32.08	28.80	26.70	25.85	23.97	23.20	21.51	20.82	18.69
								X_o	24.28	21.80	20.21	19.59	17.98	17.54	16.21	15.79	14.15
	AXIAL (Completely Reversed) — Miscellaneous																
365	HT-16	M.P.	25	80	1.0		S.E.V.	β	.9297*	1.034	1.114	1.150	1.239	1.280	1.379	1.424	1.584*
								M	23.89	21.48	19.93	19.30	17.92	17.35	16.10	15.60	14.02

HT-16: Aged 750°F, 2 hr, AC, Stress Relieved, 600°F, 15 min., AC

Composition: See Page 168
(*) Extrapolated Values

AZ80A-F MAGNESIUM

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS: DIST.	Param.	LIFE IN CYCLES: 1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING — Miscellaneous																
366	HT-17	M.P.		80	1.0	Extrusions	S.E.V.	β M	.7349* 38.53	.8500* 33.31	.9410* 30.09	.9831 28.80	1.088 26.01	1.137 24.90	1.258* 22.49	1.315* 21.53	1.521* 18.61
	AXIAL (Completely Reversed) — Miscellaneous																
367	HT-17	M.P.		80	1.0	Extrusions	S.E.V.	β M	.4120* 24.62	.4538* 22.34	.4856* 20.88	.5000* 20.28	.5349* 18.96	.5508* 18.41	.5893 17.21	.6067 16.71	.6684* 15.17

HT-17: Aged 750°F, 2 hrs, AC. Stress Relieved, 600°F, 15 min.

AZ81 CAST MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	PLATE BENDING (Completely Reversed) Effect of Shot Peening																
368	T-4			80	1.0	No Peening	Weibull	b θ X_o	1.071* 35.16 31.35	1.298* 29.18 26.21	1.262 25.56 23.01	1.078 24.11 21.90	1.139 21.14 19.15	1.103 19.97 18.12	1.021 17.49 15.93	.9858 16.52 15.06	.9037* 13.67 12.50
369	T-4			80	1.0	Shot Pe, 45 psi	Weibull	b θ X_o			1.299* 23.67 22.21	1.311* 21.02 19.72	1.102 15.93 15.05	1.056 14.14 13.38	1.056* 10.74 10.15	1.056* 9.537 9.022	1.056* 6.429 6.081

HM21 MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

AXIAL (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
370				650	1.0	Forged	S.E.V.	β M	.7464* 19.80	1.047* 14.11	1.327 11.13	1.469 10.05	1.862 7.935	2.062 7.166	2.613* 5.655	2.894* 5.106	4.061* 3.639

S_u = 48 ksi
S_y = 41 ksi

ZK60A MAGNESIUM

Composition: See Page 168
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PAPAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
371	T-5	M.P. 10 RMS		80	1.0	Extrusions	S.E.V.	β M	.5816* 32.74	.6630* 28.71	.7266 26.20	.7559 25.18	.8284 22.98	.8617 22.09	.9445 20.16	.9825 19.38	1.120* 16.99
372	T-5	Ground		80	2.4	Extrusions	L.E.V.	β M	.6709* 19.46	.8129 16.06	.9297 14.04	.9851 13.25	1.126 11.59	1.193 10.94	1.365 9.565	1.446 9.028	1.752* 7.450
373	T-5	Ground		80	3.4	Extrusions	Weibull	b θ X_o	1.597* 22.15 18.11	1.736 16.44 13.30	1.686 13.33 10.83	1.686 12.19 9.900	1.686 9.891 8.033	1.686 9.040 7.341	1.686* 7.335 5.957	1.686* 6.702 5.444	1.686* 4.971 4.037

A-1.5.5 Nickel Alloys

S_u = 66 ksi
S_y = 38 ksi

"A" NICKEL

Composition: See Page 168
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	PLATE BENDING (Completely Reversed) Miscellaneous																
374	1 hr @ 500°F			80	V-Not.		Weibull	b θ X_o				.9980* 29.21 22.10	.9980* 19.80 14.98	.9980* 16.75 12.67	1.128 11.37 8.484	1.028* 9.608 7.246	1.140* 5.519 4.108
	AXIAL (Completely Reversed) Miscellaneous																
375				572	1.0		L.E.V.	β M		.3094 49.19	.4380 34.74	.5088* 29.91	.7204* 21.12	.8368* 18.19			
	THERMAL (80°F to 572°F) Miscellaneous																
376				80-572	1.0		Weibull	b θ X_o		2.203* 41.83 32.58	2.144 27.96 21.88	2.042 23.49 18.54	2.097* 15.71 12.34	2.039* 13.20 10.42			

S_u = 75 ksi

FS-27 NICKEL BASE CERMET

Composition: See Page 168
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									PLATE BENDING (Completely Reversed) Effect of Test Temperature								
377		Ground (Longitudinal)		1800	1.0		Weibull	b	1.593*	1.374	1.404	1.406	1.632	1.589	1.493	1.454	1.664*
								θ	36.83	30.92	27.39	25.99	23.05	21.87	19.36	18.37	15.45
								X_o	31.89	27.11	23.97	22.75	19.91	18.94	16.86	16.03	13.32
378		Ground (Longitudinal)		2000	1.0		S.E.V.	β	.6727*	.8276	.9566	1.018	1.176	1.252	1.447	1.541	1.896*
								M	24.95	20.28	17.54	16.48	14.26	13.40	11.59	10.89	8.853

(Test Conditions / Fatigue Strength Distributions and Their Parameters; Life in Cycles)

S_u = 120 ksi
S_y = 65 ksi

HASTELLOY C

Composition: See Page 168
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
379	Solution Heat Treated	Mechanical Polish		80	1.0		Weibull	b	1.855	1.855	1.855	1.855	1.909	1.882	1.885*	1.885*	
								θ	79.26	69.67	63.66	61.24	55.97	53.83	49.19	47.31	
								X_o	67.52	59.35	54.23	52.17	47.53	45.79	41.90	40.31	
380	Solution Heat Treated	Mechanical Polish		80	3.5		L.E.V.	β	.4415	.7166	1.005	1.1629	1.631	1.887	2.647*	3.063*	
								M	83.50	51.45	36.68	31.70	22.80	19.53	13.92	12.03	

S_u = 70 ksi

HASTELLOY - R235

Composition: See Page 168
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Heat Treatment																
331	HT-18		60	80	1.0		L.E.V.	β M					.2881 68.78	.3252* 60.94	.4308* 46.01		
382	HT-19		60	80	1.0		Weibull	b θ X_o		1.485 67.06 56.13	1.485 58.77 49.19	1.485 55.53 46.47	1.081 48.37 42.05	.8983 45.52 40.19	.6708 39.70 35.58	.8225* 37.63 33.41	.9775* 31.26 27.42
383	HT-18		60	1650	1.0		S.E.V.	β M	.3544* 49.36	.4971* 35.19	.6298 27.77	.6973 25.08	.8834* 19.80	.9782* 17.88	1.239* 14.11	1.372* 12.75	1.924* 9.089
384	HT-19		60	1650	1.0		Weibull	b θ X_o	1.608* 31.99 29.05	1.567* 30.50 27.75	1.539 29.50 26.87	1.527 29.08 26.50	1.500 28.13 25.66	1.489 27.73 25.30	1.463* 26.82 24.50	1.452* 26.44 24.16	1.415* 25.21 23.07
	Effect of Stress Concentration																
385	HT-18		60	80	1.0		L.E.V.	β M					.2881 68.78	.3252* 60.94	.4308* 46.01		
386	HT-19		60	80	3.4		Weibull	b θ X_o	5.022* 52.90 37.66	5.254* 43.89 30.74	5.822* 38.52 25.90	4.892* 36.40 26.14	5.473 31.95 22.04	5.713 30.20 20.47	5.269 26.50 18.54	5.215 25.05 17.59	5.362* 20.78 14.44

S_u = 64 ksi

HASTELLOY - R235 (Cont'd)

Composition: See Page 168
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
387	HT-18		60	80	1.0		L.E.V.	β M					.2881 68.78	.3252* 60.94	.4308* 46.01		
388	HT-18		60	1650	1.0		S.E.V.	β M	.3544* 49.36	.4971* 35.19	.6298 27.77	.6973 25.08	.8834* 19.80	.9782* 17.88	1.239* 14.11	1.372* 12.75	1.924* 9.089
389	HT-19		60	80	1.0		Weibull	b θ X_o		1.485 67.06 56.13	1.485 58.77 49.19	1.485 55.53 46.47	1.081 48.37 42.05	.8983 45.52 40.19	.6708 39.70 35.58	.8225* 37.63 33.41	.9775* 31.26 27.42
390	HT-19		60	1200	1.0		Normal	σ μ	3.540* 56.79	3.222* 51.70	3.018 48.42	2.933 47.07	2.747 44.08	2.670 42.85	2.501 40.13	2.431 39.01	2.213* 35.51
391	HT-19		60	1650	1.0		Weibull	b θ X_o	1.608* 31.99 29.05	1.567* 30.50 27.75	1.539 29.50 26.87	1.527 29.08 26.50	1.500 28.13 25.66	1.489 27.73 25.30	1.463* 26.82 24.50	1.452* 26.44 24.16	1.415* 25.21 23.07

(Column headings: TEST CONDITIONS — Heat Treat, Surf. Fin., Freq., Temp °F, K_t, Other; FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — DIST., Param., LIFE IN CYCLES.)

HT-18: Vacuum Annealed at 1850°F, 1/2 hr, F.C., 1.5 hr; tempered at 2150°F, 0.5 hr, AC Sol. H.T. at 1800°F, 4 hr, O.Q., Aged at 1350°F, 16 hrs, AC-Hot Rolled

HT-19: Preheat 1400°F, 0.5 hr, Hardened 1900, 0.5 hr, A.C., Tempered at 1050°F, 2 hrs, Retemper, 2 hrs-Cast

S_u = 182 ksi
S_y = 116 ksi

INCOLOY 901 (AMS-5560A)

Composition: See Page 168
(*) Extrapolated Values

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES: 1×10^3	1×10^4	5×10^4	1×10^5	5×10^5	1×10^6	5×10^6	1×10^7	1×10^8
	AXIAL (Completely Reversed) Effect of Test Temperature																
392	2000°F, 2 hrs, W.Q., 1450°F, 2 hrs, AC, 1325°F, 24 hrs, AC.	Mechanical Polishing	30	80	1.0	Lathe Turned or Bored	Weibull	b θ X_o	2.896* 136.2 113.0	2.862* 102.1 84.95	2.773 83.55 69.77	2.964 76.64 63.42	2.948 62.68 51.91	3.006 57.48 47.47	2.751 47.00 39.29	2.796* 43.11 35.96	2.894* 32.33 26.85
393			30	600	1.0		Normal	σ μ	5.726* 123.1	4.169* 89.67	3.339 71.83	3.035 65.28	2.431* 52.29	2.209* 47.52	1.770* 38.07	1.608* 34.60	1.171* 25.19
394			30	1000	1.0		S.E.V.	β M	.1606* 103.9	1.987 84.05	.2305 72.45	.2457 67.96	.2851 58.57	.3039* 54.94	.3526* 47.36	.3759* 44.42	.4650* 35.91
395			30	1400	1.0		S.E.V.	β M	.7488* 76.27	.8777 65.06	.9809 58.22	1.028 55.50	1.149 49.67	1.206* 47.35	1.347* 42.37	1.413* 40.39	1.657* 34.46
396			30	1800	1.0		Weibull	b θ X_o	7.858* 40.60 30.39	7.875* 27.01 20.21	7.736 20.32 15.28	7.381 17.97 13.70	7.564* 13.52 10.23	8.025* 11.96 8.899	7.959* 9.000 6.711	7.418* 7.961 6.058	7.959* 5.298 3.950

S_u = 88-89 ksi
S_y = 33-37 ksi

INCONEL

Composition: See Page 168
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	AXIAL (Completely Reversed) Effect of Frequency (Creep)																
397	Annealed at 1900°F, 1 hr		1.0	1500	1.0		L.E.V.	β M	1.084* 22.47	1.254 19.43	1.388 17.56	1.450* 16.81	1.605* 15.18	1.676* 14.54	1.855* 13.13	1.938* 12.57	2.241* 10.87
398	Annealed at 1900°F, 1 hr		.1	1500	1.0		Weibull	b θ X_o	3.974* 24.69 19.64	3.937 17.84 14.22	3.937* 14.21 11.33	3.937* 12.89 10.27	3.937* 10.27 8.190	3.937* 9.318 7.427	3.937* 7.425 5.918	3.937* 6.733 5.367	3.937* 4.866 3.878
	Effect of Test Temperature																
400	HT-20	Mechanical Polishing	153	80	1.0		S.E.V.	β M	.9047* 70.04	1.206 52.52	1.475* 42.94	1.609* 39.38	1.967* 32.20	2.145* 29.53	2.624* 24.14	2.862* 22.14	3.816* 16.60
401	HT-20	Mechanical Polishing	153	200	1.0		S.E.V.	β M	.1360* 62.15	.1510* 55.96	.1626 52.00	.1678* 50.38	.1806* 46.81	.1864* 45.35	.2006* 42.14	.2070* 40.83	.2299* 36.76
402	HT-20	Mechanical Polishing	153	400	1.0		L.E.V.	β M	.4915* 57.69	.5976 47.44	.6851 41.38	.7266* 39.02	.8330* 34.03	.8835* 32.09	1.012* 27.99	1.074* 26.39	1.306* 21.70
403	HT-20	Mechanical Polishing	153	600	1.0		L.E.V.	β M	.3652* 61.37	.4227 53.03	.4681 47.89	.4891 45.83	.5417 41.38	.5660* 39.60	.6269* 35.76	.6550* 34.22	.7580* 29.57

HT-20: Vacuum Annealed at 1850°F, 0.5 hr, F.C. in 1.5 hr; 2150°F, 0.5 hr A.C., Solution H.T. 1800°F-4 hrs, O.Q. Aged 1350°F, 16 hrs, A.C.

S_u = 88-89 ksi
S_y = 33-37 ksi

INCONEL (Cont'd)

Composition: See Page 168
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	AXIAL (Completely Reversed) Effect of Test Temperature																
404	Annealed at 1900°F 1 hr		1.0	1300	1.0		Weibull	b	6.458*	6.676	6.188	5.992	6.567*	6.397*	6.023*	6.874*	6.421*
								θ	31.06	28.78	27.28	26.66	25.28	24.70	23.42	22.89	21.20
								X_o	27.41	25.29	24.19	23.72	22.26	21.82	20.82	20.04	18.72
405	Annealed at 1900°F 1 hr		1.0	1500	1.0		L.E.V.	β	1.084*	1.254	1.388	1.450*	1.605*	1.676*	1.855*	1.938*	2.241*
								M	22.47	19.43	17.56	16.81	15.18	14.54	13.13	12.57	10.87

INCONEL 713C

Composition: See Page 169
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	AXIAL (Completely Reversed) Effect of Stress Concentration																
406		Mechanical Polishing	60	1700	1.0	Cast	Weibull	b	1.020*	1.087*	1.127*	1.144	1.179	1.194	1.206	1.206	1.168*
								θ	40.34	36.87	34.63	33.71	31.65	30.81	28.93	28.15	25.72
								X_o	36.93	33.68	31.58	30.71	28.80	28.02	26.30	25.59	23.41
407		Mechanical Polishing	60	1700	2.9	Cast	L.E.V.	β	.5602*	.6030*	.6347	.6489	.6831	.6984	.7352	.7517	.8090*
								M	34.76	32.30	30.68	30.01	28.51	27.88	26.49	25.91	24.07

S_u = 186-225 ksi
S_y = 146-194 ksi

INCONEL-X (AMS-5667)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Heat Treatment																
408	HT-21		183	80	1.0	Vacuum Melt	L.E.V.	β M	.1298* 160.8	.1723* 121.2	.2100* 99.50	.2286 91.38	.2786 74.98	.3034 68.86	.3697 56.51	.4026 51.90	.5342* 39.11
409	HT-22		183	80	1.0	Vacuum Melt	Normal	σ μ	15.06* 179.1	11.21* 133.4	9.124* 108.5	8.349* 99.32	6.794 80.82	6.217 73.95	5.058 60.17	4.629 55.06	3.446* 41.00
	AXIAL (Completely Reversed) Miscellaneous																
410				80	1.0		Normal	σ μ	6.722* 148.9	4.787 106.0	3.775 83.63	3.408 75.51	2.688 59.55	2.427* 53.77	1.914* 42.41	1.728* 38.29	1.230* 27.26

HT-21: 1200°F, 4 hrs, AC, Forged and Swaged
HT-22: Aged 1350°F, 16 hrs, AC, Forged and Swaged

S_u = 121-225 ksi
S_y = 75-189 ksi

INCONEL - 718

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Miscellaneous																
411	HT-23		167	80	1.0		S.E.V.	β	.5044*	.5623*	.6068*	.6270	.6765	.6990	.7543*	.7794*	.8691*
								M	126.9	113.8	105.4	102.0	94.62	91.57	84.86	82.13	73.66
412	HT-24		167	800	1.0		S.E.V.	β	.1596*	.1708*	.1791*	.1828*	.1916	.1956	.2051	.2093*	.2240*
								M	117.0	109.3	104.3	102.2	97.48	95.51	91.09	89.26	83.41
	AXIAL (Completely Reversed) Effect of Heat Treatment																
413	Solut. H.T.	Mechanical Polish	50	80	1.0		S.E.V.	β	.5386*	.5756	.6029	.6150	.6442*	.6572*	.6884*	.7022*	.7504*
								M	80.46	75.29	71.88	70.46	67.27	65.94	62.96	61.71	57.75
414	Stress Reliev.	Mechanical Polish	50	80	1.0		Weibull	b	1.236*	1.095*	.9548	1.537	1.392	1.045	1.440	1.627	1.806*
								θ	91.08	75.37	66.05	62.80	54.98	51.76	45.60	43.18	35.86
								X_o	80.27	66.93	58.97	54.23	47.97	46.06	39.65	37.04	30.33

HT-23: 1750°F, 1 hr, A.C. 1325°F, 8 hrs, F.C. to 1150°F and Hold for 10 hrs.
HT-24: 1325°F, 8 hrs, F.C. to 1150°F and hold for 18 hrs

S_u = 121-225 ksi
S_y = 75-189 ksi

INCONEL - 718 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS: DIST.	Param.	LIFE IN CYCLES: $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
415	Solution Heat Treated	Mechanical Polishing	50	80	1.0		S.E.V.	β	.5386*	.5756	.6029	.6130	.6442*	.6572*	.6884*	.7022*	.7504*
								M	80.46	75.29	71.88	70.46	67.27	65.94	62.96	61.71	57.75
416	Solution Heat Treated	Mechanical Polishing	50	80	3.5		Weibull	b	6.724*	6.908	6.775	6.726	6.626	6.592	6.520*	6.446*	6.183*
								θ	88.09	64.18	51.43	46.75	37.46	34.06	27.29	24.81	18.07
								X_o	49.32	35.27	28.65	26.17	21.18	19.32	15.59	14.27	10.66
417	Stress Relieved	Mechanical Polishing	50	80	1.0		Weibull	b	1.236*	1.095*	.9548	1.537	1.392	1.045	1.440	1.627	1.806*
								θ	91.08	75.37	66.05	62.80	54.98	51.76	45.60	43.18	35.86
								X_o	80.27	66.93	58.97	54.23	47.97	46.06	39.65	37.04	30.33
418	Stress Relieved	Mechanical Polishing	50	80	3.0		Weibull	b	1.088*	.7352*	1.053*	.5474*	.7763	.8313	.9320	.9679*	1.069*
								θ	37.78	32.75	29.89	28.53	25.94	24.91	22.66	21.75	18.99
								X_o	34.00	30.00	26.95	26.22	23.73	22.73	20.57	19.71	17.10
419	Stress Relieved	Mechanical Polishing	50	1000	1.0		Weibull	b	3.095*	3.047	3.016	3.003	2.974	2.962	2.935*	2.924*	2.889*
								θ	78.28	72.41	68.57	66.98	63.42	61.95	58.67	57.31	53.01
								X_o	57.61	53.52	50.82	49.70	47.18	46.14	43.80	42.82	39.73
420	Stress Relieved	Mechanical Polishing	50	1000	3.0		Weibull	b	3.372*	3.237*	3.228	3.228	3.444	3.228*	3.344*	3.244*	3.212*
								θ	77.91	48.84	35.24	30.62	22.10	19.19	13.85	12.03	7.547
								X_o	55.44	35.20	25.42	22.08	15.62	13.84	9.885	8.670	5.452

S_u = 121-225 ksi
S_y = 75-189 ksi

INCONEL - 718 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Stress Concentration																
421	Stress Relieved		50	1400	1.0		Normal	σ μ	3.024* 48.36	2.913 46.60	2.839 45.40	2.807 44.90	2.735 43.75	2.705 43.26	2.635 42.15	2.606 41.68	2.511* 40.16
422	Stress Relieved		50	1400	3.0		I.E.V.	β M	.7166* 25.44	.7806* 23.35	.8287 22.00	.8503 21.44	.9027 20.20	.9262 19.68	.9833 18.54	1.008 18.07	1.099* 16.59
	Effect of Test Temperature																
423	Stress Relieved		50	80	1.0		Weibull	b θ X_o	1.236* 91.08 80.27	1.095* 75.37 66.93	.9548 66.05 58.97	1.537 62.80 54.23	1.392 54.98 47.97	1.045 51.76 46.06	1.440 45.60 39.65	1.627 43.18 37.04	1.806* 35.86 30.33
424	Stress Relieved		50	1000	1.0		Weibull	b θ X_o	3.095* 78.28 57.61	3.047 72.41 53.52	3.016 68.57 50.82	3.003 66.98 49.70	2.974 63.42 47.18	2.962 61.95 46.14	2.935* 58.67 43.80	2.924* 57.31 42.82	2.889* 53.01 39.73
425	Stress Relieved		50	1200	1.0		Weibull	b θ X_o	1.068* 63.97 59.70	1.182 59.09 54.89	1.261 55.89 51.75	.8946 54.37 51.06	.7890 51.34 48.37	.8509 50.14 47.16	.9745 47.46 44.45	1.024* 46.35 43.33	1.160* 42.82 39.82
426	Stress Relieved		50	1400	1.0		Normal	σ μ	3.024* 48.36	2.913 46.60	2.839 45.40	2.807 44.90	2.735 43.75	2.705 43.26	2.635 42.15	2.606 41.68	2.511* 40.16

S_u = 121-225 ksi
S_y = 75-189 ksi

INCONEL - 718 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
427	Stress Relieved		50	80	3.0		Weibull	b	1.088*	.7352*	1.053*	.5474*	.7763	.8313	.9320	.9679*	1.069*
								θ	37.78	32.75	29.89	28.53	25.94	24.91	22.66	21.75	18.99
								X_o	34.00	30.00	26.95	26.22	23.73	22.73	20.57	19.71	17.10
428	Stress Relieved		50	1000	3.0		Weibull	b	3.372*	3.237*	3.228	3.228	3.444	3.228*	3.344*	3.244*	3.212*
								θ	77.91	48.84	35.24	30.62	22.10	19.19	13.85	12.03	7.547
								X_o	55.44	35.20	25.42	22.08	15.62	13.84	9.885	8.670	5.452
429	Stress Relieved		50	1400	3.0		L.E.V.	β	.7166*	.7806*	.8287	.8503	.9027	.9262	.9833	1.008	1.099*
								M	25.44	23.35	22.00	21.44	20.20	19.68	18.54	18.07	16.59

S_u = 185 ksi
S_y = 125 ksi

WASPALLOY

Composition: See Page 169
(*) Extrapolated Values

ROTARY BEAM BENDING
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
430	HT-25			80	1.0		Normal	σ	9.185*	7.641*	6.719*	6.356*	5.589	5.288	4.650	4.399	3.659*
								μ	128.6	107.0	94.11	89.04	78.29	74.07	65.13	61.62	51.26

HT-25: Sol. H.T. 1975°F, 4 hrs, A.C., Aged 1550°F, 24 hrs, A.C. Aged 1400°F, 16 hrs, A.C.

S_u = 174 ksi
S_y = 115 ksi

INCONEL - 751 (INCO-X550)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						**FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS** — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Test Temperature																
431	HT-26	Lapped 10 RMS		80	3.4	Hot Rolled	S.E.V.	β M	.1607* 100.1	.2327* 69.17	.3014* 53.40	.3369 47.77	.4364 36.88	.4878 32.99	.6319 25.47	.7063* 22.78	1.022* 15.74
432	HT-26	Lapped 10 RMS		1350	3.4	Hot Rolled	L.E.V.	β M	.1847* 40.88	.2108* 35.81	.2313 32.64	.2407 31.36	.2640 28.59	.2747 27.47	.3014 25.04	.3137 24.06	.3581* 21.08
	Miscellaneous																
433	HT-26	M.P. 10 RMS		1500	1.0	Hot Rolled	Weibull	b θ X_o	1.434* 96.98 93.30	.9463* 75.43 73.17	.7951* 63.30 61.54	1.434* 58.81 56.58	1.155* 49.35 47.71	.8998* 45.73 44.39	1.434 38.45 36.99	1.419 35.66 34.32	.8941* 27.73 26.92

HT-26: Sol. H.T. 2150°F, 1 hr, AC, Aged 1600°F, 4 hrs, AC, Aged 1350°F, 4 hrs, AC

INOR - 8

Composition: See Page 169
(*) Extrapolated Values

†Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING Effect of Test Temperature																
434	HT-27	Mechanical Polishing		1100	1.0		Normal	σ	5.861*	5.392	5.086	4.960	4.680	4.564	4.305*	4.198*	3.863*
								μ	73.59	67.70	63.87	62.29	58.76	57.30	54.06	52.72	48.50
435	HT-27	Mechanical Polishing		1300	1.0		L.E.V.	β	.2343*	.2581*	.2761	.2843	.3042	.3132	.3352	.3451	.3801*
								M	60.58	54.99	51.39	49.92	46.65	45.31	42.34	41.13	37.33
436	HT-27	Mechanical Polishing		1500	1.0		Normal	σ	5.624*	4.982	4.577	4.412	4.054	3.908	3.590	3.462	3.066*
								μ	52.86	46.82	43.02	41.47	38.10	36.73	33.75	32.54	28.82

(Column group: FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES)

S_u = 76 ksi
S_y = 37 ksi

MONEL

Composition: See Page 169
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Miscellaneous

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
437	1 hr @ 932°F			80	V-Not.		Weibull	b	1.341*	1.341*	1.341*	1.341*	1.341*	1.341	1.341	1.341*	1.341*
								θ	17.60	14.27	12.32	11.57	9.992	9.380	8.100	7.605	6.165
								X_o	11.02	8.939	7.719	7.247	6.258	5.875	5.073	4.763	3.861

HT-27: Solution Annealed at 2100°F, 1 hr, AC, Stress Relieved at 1600°F, 1 hr.

S_u = 130 ksi
S_y = 120 ksi

NICRO - TUNG

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES: 1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
438			50	1200	1.0		S.E.V.	β M	.1709* 87.10	.2141* 69.53	.2506* 59.40	.2681* 55.51	.3139 47.42	.3359 44.31	.3932 37.86	.4208 35.38	.5271* 28.24
439			50	1200	2.0		L.E.V.	β M	.3356* 48.33	.3858* 42.04	.4253* 38.14	.4435 36.57	.4888 33.18	.5098* 31.82	.5619* 28.87	.5860* 27.68	.6735* 24.08
440			50	1500	1.0		L.E.V.	β M	.1610* 57.79	.1857* 50.11	.2051* 45.36	.2141 43.45	.2366 39.33	.2469 37.68	.2728 34.10	.2848 32.67	.3285* 28.33
441			50	1500	2.0		Weibull	b θ X_o	.9361* 47.79 44.58	.9361* 42.83 39.95	.9361 39.68 37.00	.9361 38.39 35.80	.9361* 35.56 33.16	.9361* 34.40 32.09	.9361* 31.87 29.72	.9361* 30.83 28.76	.7175 27.56 25.92
442			50	1700	1.0		Weibull	b θ X_o	1.840* 53.75 45.85	1.840* 45.36 38.70	1.840* 40.29 34.37	1.840* 38.28 32.66	1.840 34.00 29.01	1.840 32.31 27.56	1.874 28.70 24.44	1.839 27.27 23.26	1.840* 23.01 19.63
443			50	1700	2.0		S.E.V.	β M	.5905* 35.40	.6181* 33.84	.6379 32.79	.6466 32.35	.6673 31.35	.6764 30.92	.6981 29.97	.7076* 29.56	.7402* 28.26

S_u = 130 ksi
S_y = 120 ksi

NICRO - TUNG (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Test Temperature																
444			50	1200	1.0		S.E.V.	β M	.1709* 87.10	.2141* 69.53	.2506* 59.40	.2681* 55.51	.3139 47.42	.3359 44.31	.3932 37.86	.4208 35.38	.5271* 28.24
445			50	1500	1.0		L.E.V.	β M	.1610* 57.79	.1857* 50.11	.2051* 45.36	.2141 43.45	.2366 39.33	.2469 37.68	.2728 34.10	.2848 32.67	.3285* 28.33
446			50	1700	1.0		Weibull	b θ X_o	1.840* 53.75 45.85	1.840* 45.36 38.70	1.840* 40.29 34.37	1.840* 38.28 32.66	1.840 34.00 29.01	1.840 32.31 27.56	1.874 28.70 24.44	1.839 27.27 23.26	1.840* 23.01 19.63
447			50	1200	2.0		L.E.V.	β M	.3356* 48.33	.3858* 42.04	.4253* 38.14	.4435 36.57	.4888 33.18	.5098* 31.82	.5619* 28.87	.5860* 27.68	.6735* 24.08
448			50	1500	2.0		Weibull	b θ X_o	.9361* 47.79 44.58	.9361* 42.83 39.95	.8361 39.68 37.00	.9361 38.39 35.80	.9361* 35.56 33.16	.9361* 34.40 32.09	.9361* 31.87 29.72	.9361* 30.83 28.76	.7175* 27.56 25.92
449			50	1700	2.0		S.E.V.	β M	.5909* 35.40	.6181* 33.84	.6379 32.79	.6466 32.35	.6673 31.35	.6764 30.92	.6981 29.97	.7076* 29.56	.7402* 28.26

S_u = 44-87 ksi
S_y = 35-76 ksi

NIMONIC - 95

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Heat Treatment

+Code No.	Heat Treat.	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
450	HT-28		98	1560	1.0		L.E.V.	β M	.2939* 83.70	.3678* 66.87	.4304* 57.16	.4605* 53.42	.5387 45.66	.5764 42.68	.6743 36.48	.7215 34.09	.9031* 27.24
451	HT-30		98	1560	1.0		Weibull	b θ X_o			1.559* 76.40 66.54	1.520* 70.09 61.18	1.614* 57.43 49.86	1.796* 52.76 45.29	1.490 43.13 37.71	1.469 39.58 34.64	1.478* 29.74 26.02
452	HT-28		98	1600	1.0		S.E.V.	β M		.2396* 69.18	.2855* 58.08	.3078* 53.86	.3667 45.22	.3953 41.94	.4709 35.21	.5078 32.65	.6522 25.42
453	HT-30		98	1600	1.0		Weibull	b θ X_o			.7102* 71.59 60.96	.7782* 64.61 54.68	.5409* 50.19 43.25	.6295* 45.31 38.83	.7440 35.65 30.27	.7720 32.12 27.20	.7720* 22.65 19.18
454	HT-29		98	1650	1.0		S.E.V.	β M	.3098* 72.74	.3809* 59.16	.4401* 51.21	.4683* 48.12	.5411 41.65	.5758 39.14	.6653 33.87	.7079 31.83	.8704* 25.89
455	HT-30		98	1650	1.0		S.E.V.	β M		.1343* 66.82	.1610* 55.73	.1741 51.54	.2088 42.98	.2257 39.75	.2707 33.15	.2927 30.66	.3795* 23.65

HT-28: 1200°C, 1.5 hrs., 1080°C, 6.5 hrs., A.C., 700°C, 16 hrs., A.C.
HT-29: Forged 2150°F, 1 hr., O.Q., Aged 1325°F 16 hrs., A.C.
HT-30: 1150°C, 4 hrs., A.C., 1080°C, 8 hrs., A.C.; 700°C 16 hrs, A.C.

S_u = 44-87 ksi
S_y = 35-76 ksi

NIMONIC - 95 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
456	HT-28		98	1560	1.0		L.E.V.	β M	.2939* 83.70	.3678* 66.87	.4304* 57.16	.4605* 53.42	.5387 45.66	.5764 42.68	.6743 36.48	.7215 34.09	.9031* 27.24
457	HT-28		98	1600	1.0		S.E.V.	β M		.2396* 69.18	.2855* 58.08	.3078* 53.86	.3667 45.22	.3953 41.94	.4709 35.21	.5078 32.65	.6522 25.42
458	HT-30		98	1560	1.0		Weibull	b θ X_o			1.559* 76.40 66.54	1.520* 70.09 61.18	1.614* 57.43 49.86	1.796* 52.76 45.29	1.490 43.13 37.71	1.469 39.58 34.64	1.478* 29.74 26.02
459	HT-30		98	1600	1.0		Weibull	b θ X_o			.7102* 71.59 60.96	.7782* 64.61 54.68	.5409* 50.19 43.25	.6295* 45.31 38.83	.7440 35.65 30.27	.7720 32.12 27.20	.7720* 22.65 19.18
460	HT-30		98	1650	1.0		S.E.V.	β M	.1036* 86.63	.1343* 66.82	.1610* 55.73	.1741 51.54	.2088 42.98	.2257 39.75	.2707 33.15	.2927 30.66	.3795* 23.65
461	HT-30		98	1740	1.0		Weibull	b θ X_o	1.219* 64.07 53.99	1.280* 50.81 42.59	1.280* 43.19 36.20	1.280* 40.27 33.75	1.280 34.22 28.68	1.269 31.91 26.77	1.130 27.08 22.99	1.310 25.29 21.15	1.160* 20.01 16.95

S_u = 182-197 ksi
S_y = 131-150 ksi

RENE - 41 (AMS-5713)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING — Miscellaneous								
462	HT-31			80	1.0		Weibull	b	3.691*	3.438*	3.438*	3.691	3.691	3.691	3.737	3.556*	3.647*
								θ	175.9	143.7	124.7	117.4	101.9	95.93	83.29	78.35	64.01
								X_o	128.3	106.9	92.84	85.66	74.37	69.97	60.53	57.77	46.86
									PLATE BENDING (Completely Reversed) — Effect of Test Temperature								
463	HT-32	Milled 90 RMS		700	1.0		Weibull	b	3.183*	3.202*	3.154*	3.136	3.102	3.091	3.091	3.091	3.160*
								θ	123.3	86.98	68.12	61.31	48.02	43.22	33.86	30.47	21.49
								X_o	65.78	46.21	36.53	32.99	26.01	23.46	18.38	16.54	11.51
464	HT-32	Milled 90 RMS		1400	1.0		Normal	σ	16.51*	12.77*	10.67	9.881	8.257	7.643	6.387	5.912	4.57[illegible]*
								μ	72.28	55.91	46.72	43.24	36.14	33.45	27.95	25.87	20.01
									Miscellaneous								
465	HT-32	Milled 90 RMS		80	7.0		Weibull	b	3.299*	3.446*	3.229*	3.446	3.447	3.447	3.446	3.446	3.439*
								θ	127.3	93.76	75.64	69.00	55.68	50.77	40.97	37.36	27.49
								X_o	90.47	65.70	54.06	48.34	39.01	35.57	28.71	26.18	19.27

HT-31: 1975°F, 1 hr., O.Q., 1650°F, 4 hrs., A.C.
HT-32: 1950°F, 0.5 hr., A.C.; 1400°F, 16 hrs., A.C., Hot Rolled
HT-33: 1975°F, W.Q., 1400°F, 16 hrs., A.C. (Vacuum melted and Hot Rolled)

S_u = 182-197 ksi
S_y = 131-150 ksi

RENE - 41 (AMS-5713) (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS		LIFE IN CYCLES								
	AXIAL (Completely Reversed) Miscellaneous																
466	HT-33	MP 16 RMS		80	1.0		Normal	σ μ	4.592* 136.6	3.991* 118.7	3.618 107.6	3.468 103.2	3.144 93.59	3.014 89.72	2.732* 81.34	2.619* 77.97	2.276* 67.77

S_u = 105 ksi
S_y = 81 ksi

NIMONIC - 80A

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Mixceilaneous

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
467	Annealed		98	1380	1.0		S.E.V.	β M	.2041* 69.89	.2280* 62.57	.2463 57.92	.2547 56.02	.2751 51.85	.2845 50.15	.3073 46.42	.3177 44.90	.3549* 40.20
468	Annealed		98	1500	1.0		Weibull	b θ X_o	2.852* 49.99 21.99	2.852 46.64 20.52	2.852 44.43 19.54	2.852 43.51 19.14	2.852 41.45 18.23	2.852 40.59 17.86	2.852 38.67 17.01	2.852 37.87 16.66	2.852* 35.33 15.54
469	Annealed		98	1600	1.0		Weibull	b θ X_o	2.954* 61.73 36.26	2.954* 50.68 29.77	2.954 44.15 25.93	2.954 41.60 24.44	2.954 36.24 21.29	2.828 34.14 20.51	2.828 29.74 17.87	2.954 28.04 16.47	2.954 23.01 13.52

S_u = 183-188 ksi
S_y = 111-147 ksi

UDIMET - 500

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						**FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES**										
	ROTARY BEAM BENDING Miscellaneous																
470	HT-34		183	80	1.0		Normal	σ	9.187*	6.621*	5.266*	4.771*	3.795	3.439	2.735	2.478	1.786*
								μ	170.7	123.0	97.89	88.70	70.55	63.92	50.84	46.07	33.20
	PLATE BENDING (Completely Reversed) Effect of Coating																
471	HT-35		30	1800	1.0	No Coating	Normal	σ	6.965*	5.296*	4.373	4.027	3.325	3.062	2.528	2.328	1.770*
								μ	51.96	39.51	32.62	30.04	24.80	22.84	18.86	17.37	13.20
472	HT-35		30	1800	1.0	Chrome Plated	Weibull	b	2.412*	2.412	2.412	2.706	2.414	2.711	2.496	2.417	2.606*
								θ	49.20	36.15	29.14	26.57	21.41	19.52	15.73	14.33	10.53
								X_o	42.81	31.45	25.35	22.81	18.63	16.75	13.63	12.47	9.088
473	HT-35		30	1800	1.0	Aluminized	Weibull	b	2.128*	2.234*	2.163	2.136	2.102	2.102	2.102	2.222	2.102*
								θ	57.58	42.36	34.16	31.14	25.12	22.90	18.47	16.85	12.38
								X_o	45.57	33.25	26.97	24.63	19.92	18.16	14.65	13.24	9.824

HT-34: Normalized 1350°F, 45 min. Hard. 1700°F, 45 min. O.Q., Tempered 600°F, 1.5 hrs., SR 600°F, 1.5 hrs.
HT-35: 2100°F, 4 hrs., A.C., 1975°F, 4 hrs., A.C., 1400°F, 16 hrs., A.C.
HT-36: Sol. H.T., 1975°F, 4 hrs., A.C., Aged 1550°F, 24 hrs., A.C.; Aged 1400°F, 16 hrs, A.C.

S_u = 183-188 ksi
S_y = 111-147 ksi

UDIMET - 500 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	PLATE BENDING (Completely Reversed) Effect of Frequency																
474	HT-35		30	1800	1.0		Normal	σ μ	6.965* 51.96	5 296* 39.51	4.373 32.62	4.027 30.04	3.325 24.80	3.062 22.84	2.528 18.86	2.328 17.37	1.770* 13.20
475	HT-35		132	1800	1.0		S.E.V.	β M	.1784* 54.91	.2348* 41.72	.2845 34.43	.3090 31.70	.3744 26.16	.4067 24.09	.4928 19.88	.5352 18.30	.7044* 13.90
	Effect of Test Temperature																
476	HT-36		132	1600	1.0		L.E.V.	β M	.1980* 75.58	.2353* 63.61	.2654* 56.39	.2795 53.54	.3153 47.46	.3321 45.06	.3746 39.95	.3946 37.93	.4688* 31.92
477	HT-36		132	80	1.0		S.E.V.	β M	.1015* 108.6	.1238* 89.09	.1422* 77.56	.1510* 73.07	.1734 63.61	.1841 59.92	.2115 52.16	.2245 49.14	.2737* 40.30
478	HT-35		132	1800	1.0		S.E.V.	β M	.1784* 54.91	.2348* 41.72	.2845 34.43	.3090 31.70	.3744 26.16	.4067 24.09	.4928 19.88	.5352 18.30	.7044* 13.90
479	HT-35		132	1200	1.0		Weibull	b θ X_o	1.125* 90.62 71.91	1.078* 74.30 59.24	1.000* 64.63 51.89	1.094 60.99 48.54	.9916 53.03 42.61	1.024 49.99 40.05	1.088 43.58 34.71	1.111 41.07 32.64	1.175* 33.74 26.63

HT-37: Sol. H.T., 1975°F, 4 hrs., O.Q. Aged 1550°F, 24 hrs., A.C., Aged 1400°F, 16 hrs., A.C.

S_u = 183-188 ksi
S_y = 111-147 ksi

UDIMET - 500 (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Miscellaneous																
480	HT-37		60	1650	1.0		Weibull	b	1.104*	1.435*	1.385*	1.364*	1.319	1.303	1.303	1.303	1.303*
								θ	64.76	55.50	49.71	47.41	42.48	40.51	36.31	34.63	29.60
								X_o	58.56	49.34	44.32	42.32	38.01	36.28	32.51	31.01	26.51

S_u = 209 ksi
S_y = 181 ksi

UDIMET - 650

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Miscellaneous																
481	HT-38	Machined		80	1.0	Vacuum Melt	L.E.V.	β		.1173*	.1433	.1563	.1910	.2082	.2544*	.2773*	.3695*
								M		136.3	111.5	102.3	83.76	76.83	62.87	57.67	43.29

HT-38: 1950°F, 1 hr., A.C., 1400°F, 10 hrs., F.C. to 1200°F and hold for 10 hrs.

S_u = 156 ksi
S_y = 96 ksi

6 Mo - WASPALLOY

Composition: See Page 169
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Stress Concentration																
482	HT-39	Lapped - 10 RMS	60	80	2.4	Hot Rolled	S.E.V.	β	.2179*	.2734*	.3203*	.3429*	.4018	.4302	.5041	.5397	.6770*
								M	78.29	62.41	53.26	49.75	42.46	39.66	33.85	31.61	25.20
483	HT-39	Lapped - 10 RMS	60	80	3.4	Hot Rolled	Weibull	b	5.824*	5.747*	5.671	5.602	5.462	5.408	5.017	4.881	4.608*
								θ	77.37	59.53	49.56	45.80	38.13	35.23	29.33	27.10	20.85
								X_o	45.97	35.65	29.91	27.83	23.49	21.82	18.86	17.65	13.92
484	HT-39	Lapped - 10 RMS	60	1500	2.4	Hot Rolled	Weibull	b	2.911*	2.841*	2.795	2.776	2.733	2.715	2.675	2.658	3.064*
								θ	32.97	30.46	28.83	28.15	26.64	26.02	24.62	24.04	22.23
								X_o	28.52	26.43	25.05	24.48	23.21	22.68	21.50	21.00	19.11
485	HT-39	Lapped - 10 RMS	60	1500	3.4	Hot Rolled	Weibull	b	2.221*	2.148*	2.100	2.080	2.035	2.016	1.975	1.957	2.084*
								θ	30.27	27.85	26.28	25.62	24.17	23.58	22.24	21.69	19.97
								X_o	26.01	24.03	22.73	22.19	20.98	20.48	19.36	18.90	17.28
	Effect of Test Temperature																
486	HT-39	Lapped - 10 RMS	60	80	3.4	Hot Rolled	Weibull	b	5.824*	5.747*	5.671	5.602	5.462	5.408	5.017	4.881	4.608*
								θ	77.37	59.53	49.56	45.80	38.13	35.23	29.33	27.10	20.85
								X_o	45.97	35.65	29.91	27.83	23.49	21.82	18.86	17.65	13.92
487	HT-39	Lapped - 10 RMS	60	1500	3.4	Hot Rolled	Weibull	b	2.221*	2.148*	2.100	2.080	2.035	2.016	1.975	1.957	2.084*
								θ	30.27	27.85	26.28	25.62	24.17	23.58	22.24	21.69	19.97
								X_o	26.01	24.03	22.73	22.19	20.98	20.48	19.36	18.90	17.28

S_u = 156 ksi
S_y = 96 ksi

6 Mo - WASPALLOY (Cont'd)

Composition: See Page 169
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
488	HT-39	Mechanical Polish 10 RMS	60	80	1.0	Hot Rolled	Weibull	b	1.488*	1.047*	1.488	1.369	1.488	1.072	.8028	1.118	.6630*
								θ	122.1	103.1	91.98	87.43	77.84	73.87	65.61	62.53	52.75
								X_o	116.0	99.19	87.41	83.36	73.97	70.99	63.46	60.02	51.14
489	HT-39	Mechanical Polish 10 RMS	60	1200	1.0	Hot Rolled	Weibull	b	1.684*	1.684	1.684	1.684	1.671	1.684	1.647	1.600*	1.664*
								θ	78.06	71.45	67.17	65.41	61.48	59.87	56.27	54.79	50.16
								X_o	67.95	62.20	58.48	56.94	53.56	52.12	49.09	47.92	43.72
490	HT-39	Mechanical Polish 10 RMS	60	1500	1.0	Hot Rolled	L.E.V.	β	.8666*	.9308*	.9785*	.9998*	1.050	1.073	1.128	1.153	1.238*
								M	52.97	49.32	46.92	45.92	43.69	42.76	40.67	39.81	37.06
491	HT-39	Lapped - 10 RMS	60	80	2.4	Hot Rolled	S.E.V.	β	.2179*	.2734*	.3203*	.3429*	.4018	.4302	.5041	.5397	.6770*
								M	78.29	62.41	53.26	49.75	42.46	39.66	33.85	31.61	25.20
492	HT-39	Lapped - 10 RMS	60	1200	2.4	Hot Rolled	L.E.V.	β	.3861*	.4291*	.4619	.4768	.5134	.5299	.5705	.5889	.6545*
								M	42.42	38.17	35.46	34.35	31.91	30.91	28.71	27.81	25.03
493	HT-39	Lapped - 10 RMS	60	1500	2.4	Hot Rolled	Weibull	b	2.911*	2.841*	2.795	2.776	2.733	2.715	2.675	2.658	3.064*
								θ	32.97	30.46	28.83	28.15	26.64	26.02	24.62	24.04	22.23
								X_o	28.52	26.43	25.05	24.48	23.21	22.68	21.50	21.00	19.11

HT-39: Sol. H.T. 1975°F, 4 hrs, A.C. Aged 1550°F, 24 hrs., A.C., Aged 1400°F 16 hrs, A.C.

A-1.5.6 Titanium Alloys

S_u = 70-120 ksi
S_y = 57-65 ksi

COMMERCIALLY PURE TITANIUM (Ti-A55)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING — Effect of Frequency																
494	Cold drawn and Annealed		30	80	1.0		Normal	σ μ	4.714* 93.03	4.073 80.38	3.677 72.58	3.519 69.46	3.177 62.71	3.041 60.01	2.745* 54.188	2.627* 51.85	
495	Cold drawn and Annealed		15	80	1.0		Weibull	b θ X_o	1.941* 102.8 85.27	1.941 84.96 70.46	1.941 74.36 61.67	1.941 70.21 58.23	1.941 61.45 50.97	1.941 58.02 48.12	1.941* 50.78 42.12	1.941* 47.95 39.77	
496	Cold drawn and Annealed		30	80	3.5		S.E.V.	β M	.3653 76.03	.7346 37.81	1.197* 23.20	1.477* 18.80	2.407* 11.54	2.970* 9.353	4.840* 5.740	5.972* 4.651	
497	Cold drawn and Annealed		15	80	3.5		L.E.V.	β M	.1947* 71.15	.2856 48.52	.3732 37.13	.4188 33.08	.5473 25.31	.6142 22.56	.8026* 17.26	.9007 15.38	
	Effect of Impurities																
498	Vacuum Annealed 1 hr. at 1500°F	Mechanical Polish - 8 RMS	167	80	1.0	18 ppm H_2	S.E.V.	β M	.2486* 76.20	.2809 67.44	.3060 61.92	.3174 59.69	.3457 54.81	.3586 52.83	.3906 48.51	.4052* 46.76	
499	Vacuum Annealed 1 hr. at 1500°F	Mechanical Polish - 8 RMS	167	80	1.0	390 ppm H_2	Weibull	b θ X_o	7.005* 74.85 43.85	6.947* 69.40 40.87	6.909 65.83 38.89	6.893 64.34 38.07	6.856 61.03 36.23	6.844 59.66 35.46	6.810* 56.59 33.73	6.795* 55.32 33.01	

S_u = 70-120 ksi
S_y = 57-65 ksi

COMMERCIALLY PURE TITANIUM (Cont'd)
(Ti-A55)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Impurities																
500	Vacuum Annealed 1 hr. at 1500 °F	Mechanical Polish-8 RMS	167	80	3.0	18 ppm H_2	Weibull	b	1.127*	.9784*	1.514	1.514	1.130	1.020	.7489*	.8576*	
								θ	52.52	42.26	36.66	34.36	29.41	27.52	23.58	22.14	
								X_o	46.17	37.59	31.13	29.18	25.85	24.40	21.27	19.85	
501	Vacuum Annealed 1 hr. at 1500 °F	Mechanical Polish-8 RMS	167	80	3.0	390 ppm H_2	Weibull	b	2.266*	2.158*	2.360	2.337	2.288	2.269	2.265*	2.265*	
								θ	61.68	49.18	42.01	39.24	33.50	31.29	26.71	24.95	
								X_o	50.18	40.31	33.94	31.76	27.71	25.45	21.73	20.30	
	Effect of Stress Concentration																
502			30	80	1.0		Normal	σ	4.714*	4.073	3.677	3.519	3.177	3.041	2.745*	2.627*	
								μ	93.03	80.38	72.58	69.46	62.71	60.01	54.188	51.85	
503			30	80	1.8		Normal	σ	5.060*	3.683	2.949	2.680	2.146	1.950*	1.562*	1.419*	
								μ	89.50	65.13	52.16	47.40	37.96	34.50	27.63	25.11	
504			30	80	2.5		Weibull	b	3.196*	3.145	3.196	3.196	3.196	3.196	3.156*	3.177*	
								θ	80.92	56.45	43.89	39.38	30.62	27.47	21.36	19.16	
								X_o	54.37	38.14	29.49	26.46	20.57	18.46	14.41	12.90	

S_u = 70-120 ksi
S_y = 57-65 ksi

COMMERCIALLY PURE TITANIUM (Cont'd)
(Ti-A55)

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
505			30	80	3.5		S.E.V.	β M	.3653 76.03	.7346 37.81	1.197* 23.20	1.477* 18.80	2.407* 11.54	2.970* 9.353	4.840* 5.740	5.972* 4.651	
506			30	80	4.7		S.E.V.	β M	.1251* 68.42	.1889 45.32	.2520 33.98	.2853 30.02	.3804 22.51	.4307* 19.88	.5744* 14.91	.6502* 13.17	
507			15	80	1.0		Weibull	b θ X_o	1.941* 102.8 85.27	1.941 84.96 70.46	1.941 74.36 61.68	1.941 70.21 58.23	1.941 61.45 50.97	1.941 58.02 48.12	1.941* 50.78 42.12	1.941* 47.95 39.77	
508			15	80	3.5		L.E.V.	β M	.1947* 71.15	.2856 48.52	.3732 37.13	.4188 33.08	.5473 25.31	.6142 22.56	.8026* 17.26	.9007* 15.38	
509			167	80	1.0		S.E.V.	β M	.1800* 92.05	.2169 76.38	.2472 67.04	.2614 63.37	.2979 55.62	.3151 52.58	.3590 46.15	.3798* 43.63	
510			167	80	3.5		Normal	σ μ	11.00 72.63	8.309 54.82	6.825 45.03	6.271 41.37	5.151 33.99	4.733 31.23	3.888 25.65	3.572 23.57	

S_u = 70-120 ksi
S_y = 57-65 ksi

COMMERCIALLY PURE TITANIUM (Cont'd)
(Ti-A55)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Stress Concentration																
511	Vacuum Annealed at 1500 °F	Mechanical Polishing-8 RMS	167	80	1.0	18 ppm Hydrogen	S.E.V.	β	.2486*	.2809	.3060	.3174	.3457	.3586	.3906	.4052*	
								M	76.20	67.44	61.92	59.69	54.81	52.83	48.51	46.76	
512	Vacuum Annealed at 1500 °F	Mechanical Polishing-8 RMS	167	80	3.0	18 ppm Hydrogen	Weibull	b	1.127*	.9784*	1.514	1.514	1.130	1.020	.7489*	.8576*	
								θ	52.52	42.26	36.66	34.36	29.41	27.52	23.58	22.14	
								X_o	46.17	37.59	31.13	29.18	25.85	24.40	21.27	19.85	
513	Vacuum Annealed at 1500 °F	Mechanical Polishing-8 RMS	167	80	1.0	390 ppm Hydrogen	Weibull	b	7.005*	6.947*	6.909	6.893	6.856	6.844	6.810*	6.795*	
								θ	74.85	69.40	65.83	64.34	61.03	59.66	56.59	55.32	
								X_o	43.85	40.87	38.89	38.07	36.23	35.46	33.73	33.01	
514	Vacuum Annealed at 1500 °F	Mechanical Polishing-8 RMS	167	80	3.0	390 ppm Hydrogen	Weibull	b	2.266*	2.158*	2.360	2.337	2.288	2.269	2.265*	2.265*	
								θ	61.68	49.18	42.01	39.24	33.50	31.29	26.71	24.95	
								X_o	50.18	40.31	33.94	31.76	27.71	25.45	21.73	20.30	

S_u = 86-107 ksi
S_y = 65-88 ksi

Ti - 75A

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Surface Finish																
515	Annealed	Machined	100	80	3.2	V Notch	Weibull	b θ X_o	4.909* 43.39 30.65	4.909* 34.55 24.41	4.909* 29.47 20.81	4.906 27.51 19.44	4.916 23.46 16.57	4.704 21.91 15.70	4.884* 18.68 13.22	4.741* 17.44 12.47	
516	Annealed	Diamond Ground	100	80	3.2	V Notch	S.E.V.	β M	.2077* 52.04	.2814* 38.42	.3479 31.07	.3812 28.36	.4712 22.94	.5163 20.93	.6383* 16.93	.6994* 15.45	
517	Annealed	Surface Rolled	100	80	2.4	V Notch	Weibull	b θ X_o	1.786* 84.08 79.00	1.786* 75.17 70.63	1.786 69.50 65.31	1.786 67.20 63.14	2.273 62.18 57.78	2.233 60.11 55.91	2.142* 55.58 51.80	2.105* 53.73 50.12	
518	Annealed	S.R. & D. Ground	100	80	2.4	LTB	S.E.V.	β M	.3816* 55.71	.5038* 42.20	.6117 34.76	.6650 31.97	.8074 26.33	.8778 24.22	.1065* 19.94	1.158* 18.35	
519	Annealed	Machined	100	80	2.4	Radius Notch	Weibull	b θ X_o	1.359* 58.80 54.86	1.570* 55.01 51.05	1.629 52.49 48.64	1.651 51.44 47.64	1.692 49.08 45.40	1.705 48.10 44.47	1.651 45.88 42.49	1.629* 44.96 41.66	
	Miscellaneous																
520	Annealed	M.P.	167	80	1.0	LTB	Normal	σ μ	4.424* 70.72	3.795 60.66	3.409 54.49	3.255 52.03	2.924 46.73	2.792 44.62	2.508* 40.08	2.394* 38.27	

S_u = 86-107 ksi
S_y = 65-38 ksi

Ti - 75A (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
									ROTARY BEAM BENDING — Effect of Frequency								
521	Annealed		6.66	80	1.0		Weibull	b	1.590*	1.661	1.860	1.385	1.483	1.408	1.280*	1.429*	
								θ	75.45	68.07	63.37	61.36	57.11	55.36	51.50	49.94	
								X_o	70.77	63.74	59.03	57.83	53.71	52.14	48.63	47.02	
522	Annealed		30	80	1.0		Weibull	b	1.647*	1.398	1.464	1.564	1.741*	1.741*	1.241*	1.383*	
								θ	76.33	64.14	56.81	53.92	47.77	45.34	40.13	38.09	
								X_o	73.89	62.27	55.12	52.25	46.19	43.83	39.02	36.98	
523	Annealed		167	80	1.0		L.E.V.	β	.3759*	.4356	.4829	.5048	.5596	.5850*	.6485*	.6779*	
								M	70.91	61.19	55.20	52.80	47.63	45.56	41.10	39.32	
									Effect of Stress Concentration								
524	Annealed	Machined	100	80	2.4	V Notch	Weibull	b	1.359*	1.570*	1.629	1.651	1.692	1.705	1.651	1.629*	
								θ	58.80	55.01	52.49	51.44	49.08	48.10	45.88	44.96	
								X_o	54.86	51.05	48.64	47.64	45.40	44.47	42.49	41.66	
525	Annealed	Machined	100	80	2.8	Square Notch	Weibull	b	8.255*	8.107*	8.019*	7.986	7.916	7.891	7.799*	7.555*	
								θ	44.49	35.82	30.78	28.83	24.77	23.21	19.94	18.68	
								X_o	27.31	22.21	19.19	18.02	15.56	14.[illegible]	12.62	12.01	
526	Annealed	Machined	100	80	3.2	Radius Notch	Weibull	b	4.909*	4.909*	4.909*	4.906	4.916	4.704	4.884*	4.741*	
								θ	43.39	34.55	29.47	27.51	23.46	21.91	18.68	17.44	
								X_o	30.65	24.41	20.81	19.44	16.57	15.70	13.22	12.47	

S_u = 137 ksi
S_y = 132 ksi

Ti - 150A

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING								
									Effect of Stress Concentration								
527		Ground #46 Abrasive		80	1.0		Weibull	b	4.638*	4.632*	4.632*	4.431	4.632	4.431	4.805	4.391*	
								θ	80.12	75.53	72.48	71.19	68.33	67.12	64.43	63.27	
								X_o	48.78	46.02	44.16	44.35	41.63	41.81	38.49	39.59	
528		Ground #46 Abrasive		80	Notched		Weibull	b	1.166*	1.253*	1.166	1.196	1.183	1.300*	1.206*	1.169*	
								θ	64.17	46.52	37.07	33.65	26.85	24.40	19.44	17.63	
								X_o	50.04	35.91	28.91	26.15	20.89	18.72	15.09	13.74	
									Effect of Surface Finish								
529		Ground		80	1.0		Weibull	b	4.638*	4.632*	4.632*	4.431	4.632	4.431	4.805	4.391*	
								θ	80.12	75.53	72.48	71.19	68.33	67.12	64.43	63.27	
								X_o	48.78	46.02	44.16	44.35	41.63	41.81	38.49	39.59	
530		M.P.		80	1.0		Weibull	b	1.202*	1.332	1.078	1.301	1.456	1.502	.9018*	1.119*	
								θ	109.2	98.62	91.43	88.86	82.79	80.28	74.13	72.03	
								X_o	98.46	88.25	82.93	79.65	73.53	71.10	67.73	65.20	

S_u = 82 ksi
S_y = 65 ksi

Ti – 0.2 O_2

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Stress Concentration																
531	1 hr. at 1400°F A.C.	Mechanical & Electropolish		80	1.0		Normal	σ μ	3.751* 81.29	3.340* 72.38	3.080 66.74	2.974 64.45	2.742 59.43	2.648 57.38	2.442 52.91	2.358 51.10	
532	1 hr. at 1400°F A.C.	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	2.177* 52.54 41.98	2.107* 43.29 34.78	2.065 37.81 30.48	2.048 35.67 28.79	2.016 31.16 25.21	2.016 29.40 23.79	2.016 25.68 20.78	2.016 24.23 19.60	
	AXIAL (Completely Reversed) Miscellaneous																
533	HT-40						Weibull	b θ X_o	1.299* 58.45 54.78	1.444* 51.37 47.94	.9408 46.84 44.25	1.295 45.10 42.27	1.445 41.22 38.47	1.484 39.65 36.96	1.504* 36.22 33.74	1.463* 34.82 32.48	

HT-40: Vacuum Annealed at 1300°F

S_u = 85 ksi
S_y = 79 ksi

Ti - 0.2C

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Stress Concentration																
534	1 hr. at 1400°F A.C.	Mechanical & Electropolish		80	1.0		S.E.V.	β M		.3285* 78.39	.3528 73.00	.3638 70.79	.3906 65.93	.4028 63.93	.4325 59.54	.4460 57.74	
535				80	3.0		Weibull	b θ X_o	1.598* 58.24 51.83	1.419* 43.43 38.98	1.313 35.38 31.91	1.277 32.39 29.26	1.277 26.40 23.85	1.277 24.17 21.84	1.277* 19.70 17.80	1.277* 18.04 16.30	
	AXIAL (Completely Reversed) Miscellaneous																
536	HT-40	Longi. Polish		80	1.0		Normal	σ μ	3.139* 62.16	2.374* 47.01	1.953 38.68	1.795 35.56	1.477* 29.25	1.358* 26.89	1.117* 22.12	1.027* 20.34	

S_u = 81 ksi
S_y = 69 ksi

Ti - N_2

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Miscellaneous																
537	1400 °F 1 hr. A.C.	M.P. & E.P.		80	3.0		S.E.V.	β M	.2437* 60.44	.3296* 44.70	.4070 36.20	.4457 33.05	.5504 26.77	.6027 24.44	.7443* 19.80	.8150* 18.08	
	AXIAL (Completely Reversed) — Miscellaneous																
538	HT-10	Longi. Polish		80	1.0		Normal	σ μ	3.585* 74.46	2.858* 59.36	2.440 50.67	2.279 47.33	1.945* 40.40	1.817* 37.73	1.551* 32.20	1.448* 30.08	

S_u = 121 ksi
S_y = 116 ksi

Ti - 0.07 N_2 - 0.2 O_2 - 0.2C

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
539	1 hr. at 1500°F A.C.	Mechanical & Electropolish		80	1.0		S.E.V.	β M	.1425* 105.8	.1640* 91.95	.1809 83.35	.1887 79.90	.2081 72.43	.2171 69.44	.2395 62.95	.2499 60.34	
540	1 hr. at 1500°F A.C.	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	1.097* 46.15 41.54	.8025* 39.93 36.68	.9563 36.38 33.07	.9927 34.92 31.67	.6682 31.45 29.12	.7211 30.21 27.89	.8154 27.49 25.23	.8482 26.39 24.17	

S_u = 41.5 ksi @ 1800°F

K - 151A TITANIUM BASE CERMET

Composition: See Page 170
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
541		Longitudinal Ground		1800	1.0		Weibull	b		1.355	1.355	1.355	1.355	1.355	1.355	1.355	
								θ		60.68	51.56	48.07	40.84	38.08	32.36	30.17	
								X_o		44.64	37.93	35.37	30.05	28.02	23.81	22.19	
542		Longitudinal Ground		2000	1.0		Normal	σ		5.282	4.894	4.396	3.425	3.076	2.396	2.152	
								μ		40.23	31.35	28.15	21.93	19.70	15.34	13.78	

S_u = 112 ksi

K - 162B TITANIUM BASE CERMET

Composition: See Page 170
(*) Extrapolated Values

PLATE BENDING (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
543		Longitudinal Ground		1800	1.0		Normal	σ	6.946*	5.964	5.361	5.120	4.603	4.396	3.952	3.775	
								μ	54.89	47.12	42.36	40.46	36.37	34.74	31.23	29.83	
544		Longitudinal Ground		2000	1.0		Weibull	b	.7859*	.8187	.5674	.6719	.8081	.8497	.6292	.6797	
								θ	50.55	38.04	30.89	28.44	23.41	21.51	17.48	16.06	
								X_o	43.91	32.93	27.28	24.94	20.28	18.56	15.38	14.08	

S_u = 72 ksi @ 1800°F

K - 183A TITANIUM BASE CERMET

Composition: See Page 170
(*) Extrapolated Values

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									PLATE BENDING (Completely Reversed)								
									Effect of Stress Concentration								
545		Ground		2000	1.0		Weibull	b	1.840*	1.840	1.840	1.865	1.840	1.840	1.840	1.840*	
								θ	47.65	36.83	30.77	28.48	23.78	22.01	18.39	17.01	
								X_o	36.29	28.06	23.44	21.63	18.12	16.77	14.00	12.96	
546		Ground		2000	2.0		Weibull	b	4.086*	4.086	4.004	3.961	3.871	3.837	3.766	3.739*	
								θ	30.16	23.68	20.00	18.60	15.71	14.60	12.33	11.47	
								X_o	18.12	14.23	12.15	11.36	9.710	9.069	7.728	7.210	
									Effect of Test Temperature								
547		Ground		1800	1.0		L.E.V.	β	.3606*	.4080	.4449	.4617	.5034	.5225	.5697	.5913	
								M	55.99	49.48	45.38	43.72	40.10	38.64	35.44	34.14	
548		Ground		2000	1.0		Weibull	b	1.840*	1.840	1.840	1.865	1.840	1.840	1.840	1.840*	
								θ	47.65	36.83	30.77	28.48	23.78	22.01	18.39	17.01	
								X_o	36.29	28.06	23.44	21.63	18.12	16.77	14.00	12.96	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									PLATE BENDING (Completely Reversed) Effect of Heat Treatment								
549	HT-41	Liquid Honed	30	80	1.0		Weibull	b θ X_o	1.420* 184.2 144.7	1.751 122.0 93.07	1.483 91.18 71.29	1.420 80.47 63.22	1.546 60.29 46.90	1.590 53.24 41.25	1.525 39.84 31.04	1.590* 35.19 27.26	
550	HT-42	Liquid Honed	30	80	1.0		Normal	σ μ		8.433 117.0	5.648 78.36	4.752 65.94	3.182* 44.16	2.677* 37.15			
									AXIAL (Completely Reversed) Effect of Sheet Thickness								
551	HT-43	Milled & Ground Edges	30	900	1.0	.125 in. Thick	Weibull	b θ X_o	5.083* 86.87 40.65	4.941 67.85 32.56	4.878 57.09 27.71	4.854 53.00 25.82	4.804 44.60 21.92	4.783 41.40 20.42	4.596 34.83 17.72	4.558* 32.34 16.55	
552	HT-43	Milled & Ground Edges	30	900	1.0	.020 in. Thick	L.E.V.	β M	.0889* 91.88	.1299 62.89	.1693 48.25	.1898 43.05	.2474 33.03	.2773 29.47	.3615 22.61	.4051* 20.17	

HT-41: Sol. H.T. 1625°F, 15 min., W.Q., Tempered at 1050°F, 11 hrs., Heat Treat Medium: A-47 Glass
HT-42: Sol. H.T. at Mill. Tempered at 1050°F for 6 hrs.
HT-43: 1655°F, 15-30 min., 925°F, 12 hrs.

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
									AXIAL (Completely Reversed) Effect of Sheet Thickness								
553	HT-43	Milled and Ground Edges	30	80	2.8	.020 in. Thick	Weibull	b	1.323*	1.428	1.309	1.448	1.402	1.441	1.261	1.421*	
								θ	79.65	58.08	46.48	42.31	33.89	30.82	24.64	22.44	
								X_o	62.63	45.21	36.59	32.87	26.44	23.95	19.48	17.48	
554	HT-43	Milled and Ground Edges	30	80	2.8	.063 in. Thick	Weibull	b	1.037*	1.082	.9512	.9856	1.048	1.070	1.111	1.126*	
								θ	83.68	64.22	53.20	49.14	40.86	37.73	31.37	28.97	
								X_o	64.00	48.88	41.02	37.77	31.21	28.76	23.79	21.93	
555	HT-43	Milled and Ground Edges	30	80	2.8	.125 in. Thick	Normal	σ	7.307*	5.745	4.856	4.517	3.818	3.551	3.001	2.792*	
								μ	74.65	58.69	49.61	46.15	39.00	36.28	30.66	28.52	
556	HT-43	Milled and Ground Edges	30	400	2.8	.020 in. Thick	L.E.V.	β	.2166*	.2595	.2944	.3108	.3526	.3723	.4224	.4460	
								M	58.46	48.80	43.01	40.74	35.91	34.01	29.97	28.39	
557	HT-43	Milled and Ground Edges	30	400	2.8	.063 in. Thick	Weibull	b	1.930*	1.920	1.970	1.930	1.931	1.981	1.924	1.903*	
								θ	80.61	58.30	46.51	42.17	33.63	30.52	24.32	22.06	
								X_o	57.96	41.97	33.28	30.32	24.18	21.81	17.50	15.91	
558	HT-43	Milled and Ground Edges	30	400	2.8	.125 in. Thick	Weibull	b	1.654*	1.564	1.602	1.616	1.640	1.641	1.573	1.531*	
								θ	72.09	55.96	46.92	43.49	36.46	33.80	28.31	26.23	
								X_o	52.01	40.82	34.07	31.52	26.35	24.42	20.63	19.21	

S_u = 119-201 ksi
S_y = 84- 180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Sheet Thickness																
559	HT-43	Milled and Ground Edges	30	600	2.8	.020 in. Thick	Weibull	b θ X_o	.9897* 62.30 54.65	1.039 49.99 43.69	.9378 42.74 37.62	.9931 40.03 35.11	.6935 34.08 30.42	.7701 31.93 28.40	.8912 27.43 24.22	.9309* 25.69 22.62	
560	HT-43	Milled and Ground Edges	30	500	2.8	.063 in. Thick	Weibull	b θ X_o	2.150* 75.24 51.30	2.078 55.05 37.90	2.150 44.28 30.19	2.150 40.31 27.48	2.049 32.39 22.39	2.151 29.50 20.11	2.138 23.72 16.20	2.034* 21.58 14.94	
561	HT-43	Milled and Ground Edges	30	600	2.8	.125 in. Thick	Weibull	b θ X_o	3.549* 74.75 47.60	3.558 56.41 35.95	3.470 46.33 29.83	3.436 42.56 27.52	3.541 34.96 22.33	3.457 32.12 20.71	3.592 26.38 16.74	3.549* 24.24 15.46	
562	HT-43	Milled and Ground Edges	30	800	2.8	.020 in. Thick	Normal	σ μ	9.873* 62.68	7.742 49.15	6.532 41.47	6.071 38.54	5.123 32.52	4.761 30.23	4.017 25.50	3.734 23.70	
563	HT-43	Milled and Ground Edges	30	800	2.8	.063 in. Thick	Weibull	b θ X_o	1.919* 56.47 37.94	1.956 44.98 30.05	1.839 38.32 26.04	1.837 35.78 24.32	1.892 30.52 20.59	1.862 28.49 19.30	1.932 24.31 16.30	1.909* 22.69 15.27	
564	HT-43	Milled and Ground Edges	30	800	2.8	.125 in. Thick	L.E.V.	β M	.1780* 52.99	.2342 40.28	.2837 33.25	.3081 30.62	.3732 25.28	.4053 23.27	.4910 19.21	.5333* 17.69	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Sheet Thickness

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
565	HT-43	Milled and Ground Edges	30	900	2.8	.020 in. Thick	Weibull	b	3.813*	3.728	3.682	3.665	3.630	3.618	3.592	3.563*	
								θ	59.93	44.91	36.70	33.65	27.50	25.21	20.61	18.89	
								X_o	25.97	19.88	16.43	15.12	12.46	11.46	9.431	8.705	
566	HT-43	Milled and Ground Edges	30	900	2.8	.063 in. Thick	Normal	σ	7.134*	4.784	3.619	3.209	2.427	2.152	1.627*	1.443*	
								μ	61.36	41.15	31.13	27.60	20.87	18.51	14.00	12.41	
567	HT-43	Milled and Ground Edges	30	900	2.8	.125 in. Thick	Weibull	b	1.690*	1.619	1.647	1.625	1.691	1.656	1.584*	1.717*	
								θ	54.89	41.53	34.19	31.44	25.89	23.81	19.58	18.03	
								X_o	39.89	30.44	24.98	23.02	18.82	17.37	14.41	13.06	
568	HT-43	Ground Edges	30	400	1.0	.020 in. Thick	Weibull	b	1.097*	1.222	1.097	1.097	1.150	1.111	1.036*	1.160*	
								θ	109.3	87.11	74.09	69.16	58.97	55.02	46.84	43.79	
								X_o	89.03	70.20	60.34	56.32	47.82	44.75	38.30	35.48	
569	HT-43	Ground Edges	30	400	1.0	.063 in. Thick	Normal	σ	19.51*	13.49	10.42	9.328	7.207	6.449	4.982	4.458*	
								μ	129.7	89.67	69.28	61.99	47.90	42.86	33.11	29.63	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V(Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Sheet Thickness

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
570	HT-43	Ground Edges	30	600	1.0	.020 in. Thick	Normal	σ μ	19.88* 102.5	15.46 79.74	12.97 66.88	12.02 62.01	10.08 52.01	9.353 48.22	7.845 40.45	7.273* 37.50	
571	HT-43	Ground Edges	30	600	1.0	.063 in. Thick	Normal	σ μ	27.89* 123.7	18.65 82.75	14.08 62.48	12.48 55.36	9.425 41.80	8.350 37.03	6.305 27.96	5.586* 24.77	
572	HT-43	Ground Edges	30	800	1.0	.020 in. Thick	Weibull	b θ X_o	1.530* 100.2 75.45	1.450 75.66 57.45	1.582 62.28 46.62	1.597 57.25 42.78	1.556 47.05 35.32	1.520 43.22 32.58	1.443 35.51 26.98	1.590* 32.68 24.44	
573	HT-43	Ground Edges	30	800	1.0	.063 in. Thick	Weibull	b θ X_o	.7546* 88.94 72.39	.9953 65.12 51.10	.7156 50.94 41.63	.8323 46.48 37.45	.9262 37.21 29.54	.9562 33.79 26.69	1.011 26.98 21.11	1.030 24.48 19.08	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V(Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp, °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
574	HT-43	Milled and Ground Edges	30	400	1.0	Longitudinal Sheet = .125 in. Thick	Normal	σ μ	11.79* 108.2	9.065 83.18	7.540 69.19	6.965 63.91	5.793 53.16	5.351 49.10	4.451 40.84	4.111* 37.73	
575	HT-43	Milled and Ground Edges	30	400	2.8	Longitudinal Sheet = .125 in. Thick	Weibull	b θ X_o	1.654* 72.09 52.01	1.564 55.96 40.82	1.602 46.92 34.07	1.616 43.49 31.52	1.640 36.46 26.35	1.641 33.80 24.42	1.573 28.31 20.63	1.531* 26.23 19.21	
576	HT-43	Milled and Ground Edges	30	600	1.0	Longitudinal Sheet = .125 in. Thick	L.E.V.	β M	.9152* 92.10	.1140 73.90	.1330 63.36	.1421 59.29	.1658 50.83	.1771 47.57	.2066 40.79	.2208 38.17	
577	HT-43	Milled and Ground Edges	30	600	2.8	Longitudinal Sheet = .125 in. Thick	Weibull	b θ X_o	3.549* 74.75 47.69	3.558 56.41 35.95	3.470 46.33 29.83	3.436 42.56 27.52	3.541 34.96 22.33	3.457 32.12 20.71	3.592 26.38 16.74	3.549* 24.24 15.46	
578	HT-43	Milled and Ground Edges	30	800	1.0	Longitudinal Sheet = .125 in. Thick	L.E.V.	β M	.8963* 90.94	.1223 66.61	.1521 53.58	.1670 48.78	.2077 39.24	.2281 35.73	.2836 28.74	.3114* 26.17	
579	HT-43	Milled and Ground Edges	30	800	2.8	Longitudinal Sheet = .125 in. Thick	L.E.V.	β M	.1780* 52.99	.2342 40.28	.2837 33.25	.3081 30.62	.3732 25.28	.4053 23.27	.4910 19.21	.5333* 17.69	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V(Cont'd)

Composition: See Page 170
(*) Extrapolated Values

←Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES								
									$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Stress Concentration																
580	HT-43	Milled and Ground Edges	30	900	1.0	.125 in. Thick	Weibull	b	5.083*	4.941	4.878	4.854	4.804	4.783	4.596	4.558*	
								θ	86.87	67.85	57.09	53.00	44.60	41.40	34.83	32.34	
								X_o	40.65	32.56	27.71	25.82	21.92	20.42	17.72	16.55	
581	HT-43	Milled and Ground Edges	30	900	2.8	.125 in. Thick	Weibull	b	1.690*	1.619	1.647	1.625	1.691	1.656	1.584*	1.717*	
								θ	54.89	41.53	34.19	31.44	25.89	23.81	19.58	18.03	
								X_o	39.89	30.44	24.98	23.02	18.82	17.37	14.41	13.06	
582	HT-43	Milled and Ground Edges	30	900	1.0	.020 in. Thick	L.E.V.	β	.8896*	.1299	.1693	.1898	.2474	.2773	.3615	.4051*	
								M	91.88	62.89	48.25	43.05	33.03	29.47	22.61	20.17	
583	HT-43	Milled and Ground Edges	30	900	2.8	.020 in. Thick	Weibull	b	3.813*	3.728	3.682	3.665	3.630	3.618	3.592	3.563*	
								θ	59.93	44.91	36.70	33.65	27.50	25.21	20.61	18.89	
								X_o	25.97	19.88	16.43	15.12	12.46	11.46	9.431	8.705	
	Effect of Test Temperature																
584	HT-43	Milled and Ground Edges	30	80	1.0	.125 in. Thick	Normal	σ	15.69*	12.40	10.52	9.805	8.318	7.749	6.573	6.124*	
								μ	122.6	96.93	82.23	76.60	64.98	60.54	51.36	47.84	
585	HT-43	Milled and Ground Edges	30	400	1.0	.125 in. Thick	Normal	σ	11.79*	9.065	7.540	6.965	5.793	5.351	4.451	4.111*	
								μ	108.2	83.18	69.19	63.91	53.16	49.10	40.84	37.73	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V(Cont'd)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
									AXIAL (Completely Reversed) Effect of Test Temperature								
586	HT-43	Milled and Ground Edges	30	600	1.0	Longitudinal Sheet .125 in. Thick	L.E.V.	β M	.9152* 92.10	.1140 73.90	.1330 63.36	.1421 59.29	.1658 50.83	.1771 47.57	.2066 40.79	.2208 38.17	
587	HT-43	Milled and Ground Edges	30	800	1.0	Longitudinal Sheet .125 in. Thick	L.E.V.	β M	.8963* 90.94	.1223 66.61	.1521 53.58	.1670 48.78	.2077 39.24	.2281 35.73	.2836 28.74	.3114* 26.17	
588	HT-43	Milled and Ground Edges	30	900	1.0	Longitudinal Sheet .125 in. Thick	Weibull	b θ X_o	5.083* 86.87 40.65	4.941 67.85 32.56	4.878 57.09 27.71	4.854 53.00 25.82	4.804 44.60 21.92	4.783 41.40 20.42	4.596 34.83 17.72	4.558* 32.34 16.55	
589	HT-43	Milled and Ground Edges	30	80	2.8	.020 in. Thick	Weibull	b θ X_o	1.323* 79.65 62.63	1.428 58.08 45.21	1.309 46.48 36.59	1.448 42.31 32.87	1.402 33.89 26.44	1.441 30.82 23.95	1.261 24.64 19.48	1.421* 22.44 17.48	
590	HT-43	Milled and Ground Edges	30	400	2.8	.020 in. Thick	L.E.V.	β M	.2166* 58.46	.2595 48.80	.2944 43.01	.3108 40.74	.3526 35.91	.3723 34.01	.4224 29.97	.4460 28.39	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
591	HT-43	Milled and Ground Edges	30	600	2.8	Longitudinal Sheet .020 in. Thick	Weibull	b	.9897*	1.039	.9378	.9931	.6935	.7701	.8912	.9309*	
								θ	62.30	49.99	42.74	40.03	34.08	31.93	27.43	25.69	
								X_o	54.65	43.69	37.62	35.11	30.42	28.40	24.22	22.62	
592	HT-43	Milled and Ground Edges	30	800	2.8	Longitudinal Sheet .020 in. Thick	Normal	σ	9.873*	7.742	6.532	6.071	5.123	4.761	4.017	3.734	
								μ	62.68	49.15	41.47	38.54	32.52	30.23	25.50	23.70	
593	HT-43	Milled and Ground Edges	30	900	2.8	Longitudinal Sheet .020 in. Thick	Weibull	b	3.813*	3.728	3.682	3.665	3.630	3.618	3.592	3.563*	
								θ	59.93	44.91	36.70	33.65	27.50	25.21	20.61	18.89	
								X_o	25.97	19.88	16.43	15.12	12.46	11.46	9.431	8.705	
594	HT-43	Milled and Ground Edges	30	80	2.8	Longitudinal Sheet .063 in. Thick	Weibull	b	1.037*	1.082	.9512	.9856	1.048	1.070	1.111	1.126*	
								θ	83.68	64.22	53.20	49.14	40.86	37.73	31.37	28.97	
								X_o	64.00	48.88	41.02	37.77	31.21	28.76	23.79	21.93	
595	HT-43	Milled and Ground Edges	30	400	2.8	Longitudinal Sheet .063 in. Thick	Weibull	b	1.930*	1.920	1.970	1.930	1.931	1.981	1.924	1.903*	
								θ	80.61	58.30	46.51	42.17	33.63	30.52	24.32	22.06	
								X_o	57.96	41.97	33.28	30.32	24.18	21.81	17.50	15.91	
596	HT-43	Milled and Ground Edges	30	600	2.8	Longitudinal Sheet .063 in. Thick	Weibull	b	2.150*	2.078	2.150	2.150	2.049	2.151	2.138	2.034*	
								θ	75.24	55.05	44.28	40.31	32.39	29.50	23.72	21.58	
								X_o	51.30	37.90	30.19	27.48	22.39	20.11	16.20	14.94	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
597	HT-43	Milled and Ground Edges	30	800	2.8	.063 in. Thick	Weibull	b θ X_o	1.919* 56.47 37.94	1.956 44.98 30.05	1.839 38.32 26.04	1.837 35.78 24.32	1.892 30.52 20.59	1.862 28.49 19.30	1.932 24.31 16.30	1.909* 22.69 15.27	
598	HT-43	Milled and Ground Edges	30	900	2.8	.063 in. Thick	Normal	σ μ	7.134* 61.36	4.784 41.15	3.619 31.13	3.209 27.60	2.427 20.87	2.152 18.51	1.627* 14.00	1.443* 12.41	
599	HT-43	Milled and Ground Edges	30	80	2.8	.125 in. Thick	Normal	σ μ	7.307* 74.65	5.745 58.69	4.856 49.61	4.517 46.15	3.818 39.00	3.551 36.28	3.001 30.66	2.792* 28.52	
600	HT-43	Milled and Ground Edges	30	400	2.8	.125 in. Thick	Weibull	b θ X_o	1.654* 72.09 52.01	1.564 55.96 40.82	1.602 46.92 34.07	1.616 43.49 31.52	1.640 36.46 26.35	1.641 33.80 24.42	1.573 28.31 20.63	1.531* 26.23 19.21	
601	HT-43	Milled and Ground Edges	30	600	2.8	.125 in. Thick	Weibull	b θ X_o	3.549* 74.75 47.69	3.558 56.41 35.95	3.470 46.33 29.83	3.436 42.56 27.52	3.541 34.96 22.33	3.457 32.12 20.71	3.592 26.38 16.74	3.549* 24.24 15.46	

S_u = 119-201 ksi
S^u = 84-180 ksi

<u>Ti - 4 Al - 3 Mo - 1 V (Cont'd)</u>

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

→Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
602	HT-43	Milled and Ground Edges	30	800	2.8	.125 in. Thick	L.E.V.	β M	.1780* 52.99	.2342 40.28	.2837 33.25	.3081 30.62	.3732 25.28	.4053 23.27	.4910 19.21	.5333* 17.69	
603	HT-43	Milled and Ground Edges	30	900	2.8	.125 in. Thick	Weibull	b θ X_o	1.690* 54.89 39.89	1.619 41.53 30.44	1.647 34.19 24.98	1.625 31.44 23.02	1.691 25.89 18.82	1.656 23.81 17.37	1.584* 19.58 14.41	1.717* 18.03 13.06	
604	HT-43	Ground Edges	30	400	1.0	Longitudinal Sheet .020 in. Thick	Weibull	b θ X_o	1.097* 109.3 89.03	1.222 87.11 70.20	1.097 74.09 60.34	1.097 69.16 56.32	1.150 58.97 47.82	1.111 55.02 44.75	1.036* 46.84 38.30	1.160* 43.79 35.48	
605	HT-43	Ground Edges	30	600	1.0	Longitudinal Sheet .020 in. Thick	Normal	σ μ	19.88* 102.5	15.46 79.74	12.97 66.88	12.02 62.01	10.08 52.01	9.353 48.22	7.845 40.45	7.273* 37.50	
606	HT-43	Ground Edges	30	800	1.0	Longitudinal Sheet .020 in. Thick	Weibull	b θ X_o	1.530* 100.2 75.45	1.450 75.66 57.45	1.582 62.28 46.62	1.597 57.25 42.78	1.556 47.05 35.32	1.520 43.22 32.58	1.443 35.51 26.98	1.590* 32.68 24.44	
607	HT-43	Ground Edges	30	900	1.0	Longitudinal Sheet .020 in. Thick	L.E.V.	β M	.1658* 86.57	.2132 67.32	.2542 56.46	.2742 52.35	.3269 43.91	.3526 40.70	.4203* 34.14	.4534* 31.65	

S_u = 119-201 ksi
S_y = 84-180 ksi

Ti - 4 Al - 3 Mo - 1 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
608	HT-43	Ground Edges	30	80	1.0		Weibull	b Θ X_o	2.642* 145.5 108.3	2.642 104.9 78.16	2.642 83.56 62.21	2.642 75.74 56.39	2.614 60.28 44.99	2.535 54.63 41.05	2.597* 43.49 32.50	2.540* 39.41 29.60	
609	HT-43	Ground Edges	30	400	1.0		Normal	σ μ	19.51* 129.7	13.49 89.67	10.42 69.28	9.328 61.99	7.207 47.90	6.449 42.86	4.982 33.11	4.458* 29.63	
610	HT-43	Ground Edges	30	600	1.0		Normal	σ μ	27.89* 123.7	18.65 82.75	14.08 62.48	12.48 55.36	9.425 41.80	8.350 37.03	6.305 27.96	5.586* 24.77	

S_u = 152 ksi
S_y = 139 ksi

Ti - 4 Al - 4 Mn

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
611	16 hrs. at 1300°F, F.C.	Mechanical Polish		80	1.0		Weibull	b Θ X_o		2.116 126.8 116.1	2.116 97.81 89.63	2.610* 87.52 78.95	2.104* 67.48 61.85	2.498* 60.37 54.66			
612	16 hrs. at 1300°F, F.C.	Mechanical Polish		600	1.0		S.E.V.	β M	.2458* 123.5	.3365 90.24	.4190 72.46	.4606 65.93	.5736* 52.94	.6304* 48.17			

Ti - 5 Al - 2.5 Sn

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$

AXIAL (Completely Reversed)
Miscellaneous

613				80	1.0		S.E.V.	β M	.2013 107.6	.2324 93.23	.2569 84.32	.2683 80.76	.2966 73.04	.3097 69.95	.3425 63.27	.3576* 60.59	

S_u = 134 ksi
S_y = 126 ksi

Ti - 5 Al - 2.5 Sn - 0.07 N_2

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

614	HT-44	Mechanical & Electropolish		80	1.0		Normal	σ μ	7.116* 102.1	6.479* 92.97	6.068 87.07	5.898 84.65	5.524 79.27	5.370 77.07	5.029 72.17	4.889 70.16	
615	HT-44	Mechanical & Electropolish		80	3.0		Normal	σ μ	4.204* 72.34	3.332* 57.34	2.832 48.74	2.641 45.45	2.245 38.64	2.093 36.03	1.779 30.62	1.659 28.56	

HT-44: 1550°F. 2 hrs.. F.C. to 1100°F. A.C.

S_u = 132 ksi
S_y = 122 ksi

Ti - 5 Al - 2.5 Sn - 0.2 O_2

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
616	HT-45	Mechanical & Electropolish		80	1.0		S.E.V.	β M	.0933* 124.7	.1065* 109.2	.1169 99.51	.1217 95.60	.1336 87.12	.1390 83.70	.1526 76.26	.1588 73.27	
617	HT-45	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	2.225* 61.38 50.39	2.392* 53.70 43.60	2.322 48.88 39.88	2.294 46.94 38.37	2.231 42.73 35.07	2.206 41.04 33.74	2.431 37.39 30.28	2.410 35.91 29.12	

S_u = 144 ksi
S_y = 137 ksi

Ti - 5 Al - 2.5 Sn - .2 C

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
618	HT-44	Mechanical & Electropolish		80	1.0		S.E.V.	β M	.1078* 123.7	.1280* 104.2	.1443* 92.48	.1520* 87.83	.1713 77.90	.1804 73.98	.2034 65.62	.2142 62.32	
619	HT-44	Mechanical & Electropolish		80	3.0		L.E.V.	β M	.3471* 75.86	.4398* 59.88	.5188 50.76	.5571 47.27	.6573 40.07	.7058 37.31	.8327 31.63	.8941 29.45	

HT-45: 1600°F, 2 hrs. F.C. to 1100°F, A.C.

S_u = 160 ksi
S_y = 153 ksi

Ti - 5 Al - 2.5 Sn - 0.07 N_2 - .2(O_2) - .2 C

Composition: See Page 170
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
ROTARY BEAM BENDING Effect of Stress Concentration																	
620	HT-45	Mechanical & Electropolish		80	1.0		Weibull	b θ X_o	1.838* 120.8 104.3	1.742* 106.6 92.60	1.838 97.91 84.48	1.838 94.22 81.38	1.661 86.32 75.25	1.721 83.17 72.28	1.838 76.28 65.88	1.827 73.47 63.49	
621	HT-45	Mechanical & Electropolish		80	3.0		S.E.V.	β M	.1455* 69.03	.1760* 57.09	.2010 49.99	.2128 47.21	.2431 41.34	.2574 39.04	.2939 34.18	.3113 32.28	

S_u = 132 ksi

Ti - 6 Al

Composition: See Page 170
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING								
									Effect of Shot Peening								
622	Annealed	Hand Finish #120 Grit		80	1.0	No Peening	Weibull	b	3.194*	3.532*	3.194	3.532	3.194	3.194*	2.852*	3.532*	
								θ	122.8	106.4	96.21	92.17	83.33	79.80	72.13	69.13	
								X_o	99.51	84.58	77.94	73.26	67.50	64.64	59.54	54.95	
623	Annealed	Hand Finish #120 Grit		80	1.0	Shot Peened	Weibull	b	4.362*	4.362*	4.362	4.362	4.362	4.362	4.146	3.928*	
								θ	131.7	114.7	104.1	99.85	90.63	86.92	78.89	75.65	
								X_o	106.6	92.88	84.31	80.86	73.39	70.39	64.49	62.43	
									Effect of Stress Concentration								
624	Annealed	Ground		80	1.0		S.E.V.	β	.1489*	.1645*	.1764*	.1818	.1949	.2008	.2153	.2218	
								M	110.9	100.3	93.63	90.87	84.75	82.25	76.72	74.45	
625	Annealed	Ground		80	3.0	V Notch	Weibull	b	7.294*	7.546*	8.123	7.742	6.894	6.634	6.293*	6.226*	
								θ	70.92	49.25	38.17	34.20	26.50	23.74	18.40	16.48	
								X_o	47.74	32.66	24.43	22.41	18.25	16.60	13.11	11.79	
626	Annealed	Lathe Turned and Bored		80	2.5	Square Notch	Weibull	b	4.394*	4.768*	4.394	4.394	4.418	4.460	4.601*	4.395*	
								θ	90.54	69.07	57.14	52.67	43.59	40.17	33.25	30.64	
								X_o	70.89	53.03	44.74	41.24	34.08	31.35	25.75	23.99	
627	Annealed	Lathe Turned and Bored		80	3.0	V Notch	Weibull	b	1.781*	1.397*	1.453	1.822	1.449	1.502	1.515*	1.467*	
								θ	83.47	64.01	53.31	49.41	41.01	37.91	31.56	29.16	
								X_o	71.10	55.89	46.40	41.96	35.70	32.89	27.36	25.35	

S_u = 132 ksi

Ti - 6 Al (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Surface Finish

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
628	Annealed	Hand Finish		80	1.0		Weibull	b θ X_o	3.194* 122.8 99.51	3.532* 106.4 84.58	3.194 96.21 77.94	3.532 92.17 73.26	3.194 83.33 67.50	3.194* 79.80 64.64	2.852* 72.13 59.54	3.532* 69.13 54.95	
629	Annealed	Ground		80	1.0		S.E.V.	β M	.1489* 110.9	.1645* 100.3	.1764* 93.63	.1818 90.87	.1949 84.75	.2008 82.25	.2153 76.72	.2218 74.45	
630	Annealed	LTB		80	3.0	V-Notch	Weibull	b θ X_o	1.781* 83.47 71.10	1.397* 64.01 55.89	1.453 53.31 46.40	1.822 49.41 41.96	1.449 41.01 35.70	1.502 37.91 32.89	1.515* 31.56 27.36	1.467* 29.16 25.35	
631	Annealed	Ground		80	3.0	V-Notch	Weibull	b θ X_o	7.294* 73.92 47.74	7.546* 49.25 32.66	8.123 38.17 24.43	7.742 34.20 22.41	6.894 26.50 18.25	6.634 23.74 16.60	6.293* 18.40 13.11	6.226* 16.48 11.79	

S_u = 152-170 ksi
S_y = 128-160 ksi

Ti - 6 Al - 4 V

Composition: See Page 170
(*) Extrapolated Values

Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING — Effect of Heat Treatment								
632	HT-46	Mechanical and Hand Polish 500-600 Grit	134	80	3.0		S.E.V.	β M	.2673* 73.69	.3432* 57.40	.4086 48.20	.4405 44.71	.5245 37.55	.5655 34.83	.6733 29.25	.7259 27.13	
633	HT-47	Mechanical and Hand Polish 500-600 Grit	134	80	3.0		Weibull	b θ X_o	3.811* 73.30 53.00	3.764 60.46 43.88	3.644 52.84 38.72	3.596 49.86 36.67	3.746 43.59 31.69	3.606 41.13 30.23	3.831 35.96 25.96	3.728 33.93 24.70	
634	HT-48	Mechanical and Hand Polish 500-600 Grit	134	80	3.0		Weibull	b θ X_o	1.861* 76.58 67.97	1.660* 63.06 56.48	1.541 55.06 49.56	1.570 51.96 46.71	1.489 45.37 40.92	1.456 42.80 38.65	1.408 37.39 33.82	1.408 35.27 31.90	
									Effect of Stress Concentration								
635	HT-46	M.P. and Hand Finish	134	80	1.0		Normal	σ μ	5.989* 107.5	5.754 103.3	5.594 100.4	5.527 99.25	5.374 96.50	5.310 95.35	5.163 92.71	5.101 91.59	
636	HT-46	M.P. and Hand Finish	134	80	3.0		S.E.V.	β M	.2673* 73.68	.3432* 57.40	.4086 48.20	.4405 44.71	.5245 37.55	.5655 34.83	.6733 29.25	.7259 27.13	

HT-46: **Duplex Annealed**
HT-47: **Triplex Annealed**
HT-48: **Beta Quenched, 1800°F, 1 hr., W.C.**

S_u = 132-170 ksi
S_y = 128-160 ksi

Ti - 6 Al - 4 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	AXIAL (Completely Reversed) Effect of Stress Concentration																
637	Annealed	Milled Edges	134	800	1.0		Weibull	b	2.658*	2.658	2.656	2.644	2.617	2.606	2.582	2.571	
								θ	50.07	46.24	43.74	42.70	40.39	39.43	37.30	36.41	
								X_o	30.39	28.07	26.56	25.98	24.68	24.14	22.92	22.41	
638	Annealed	Milled Edges	134	800	3.0		Weibull	b	1.346*	1.296	1.384	1.398	1.429	1.441	1.272	1.287*	
								θ	38.34	34.60	32.23	31.25	29.10	28.22	26.23	25.44	
								X_o	29.20	26.46	24.45	23.67	21.97	21.28	20.09	19.46	
	Effect of Test Temperature																
639	Annealed	Milled Edges	134	80	1.0		Normal	σ	7.503*	6.863	6.448	6.277	5.898	5.742	5.395	5.252*	
								μ	69.39	63.47	59.63	58.05	54.54	53.10	49.89	48.57	
640	Annealed	Milled Edges	134	800	1.0		Weibull	b	2.658*	2.658	2.656	2.644	2.617	2.606	2.582	2.571	
								θ	50.07	46.24	43.74	42.70	40.39	39.43	37.30	36.41	
								X_o	30.39	28.07	26.56	25.98	24.68	24.14	22.92	22.41	
641	Annealed	Milled Edges	134	1000	1.0		S.E.V.	β	.4885*	.5040	.5151	.5200	.5315	.5366	.5484	.5536*	
								M	39.42	38.21	37.38	37.03	36.23	35.89	35.11	34.78	

S_u = 132-170 ksi
S_y = 128-160 ksi

Ti - 6 Al - 4 V (Cont'd)

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									AXIAL (Completely Reversed) Effect of Test Temperature								
642	Annealed	Milled Edges	134	600	3.0		Weibull	b	2.498*	2.482*	2.470	2.465	2.459	2.459	2.459*	2.459*	
								θ	41.99	38.90	36.87	36.03	34.16	33.38	31.64	30.92	
								X_o	30.64	28.43	26.97	26.37	25.01	24.44	23.17	22.65	
643	Annealed	Milled Edges	134	800	3.0		Weibull	b	1.346*	1.296	1.384	1.398	1.429	1.441	1.272	1.287*	
								θ	38.34	34.60	32.23	31.25	29.10	28.22	26.23	25.44	
								X_o	29.20	26.46	24.45	23.67	21.97	21.28	20.09	19.46	

S_u = 162 ksi
S_y = 150 ksi

Ti - 6 Al - 4 V - 0.07 N_2

Composition: See Page 170
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									ROTARY BEAM BENDING Effect of Stress Concentration								
644	HT-44	Mechanical & Electropolish		80	1.0		L.E.V.	β	.2198*	.2540*	.2809*	.2934*	.3246	.3390	.3750	.3916	
								M	138.2	119.6	108.1	103.5	93.65	89.67	81.06	77.62	
645	HT-44	Mechanical & Electropolish		80	3.0		Weibull	b	1.616*	1.616*	1.616	1.616	1.616	1.616	1.616	1.616	
								θ	74.97	58.55	49.26	45.73	38.48	35.72	30.05	27.90	
								X_o	65.39	51.07	42.97	39.89	33.56	31.15	26.21	24.33	

HT-44: 1550°F, 2 hrs., F.C. to 1100°F, A.C.

S_u = 161 ksi
S_y = 152 ksi

Ti - 6 Al - 4 V - 0.2 O_2

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
646	HT-45	Mechanical & Electropolish		80	1.0		L.E.V.	β M	.1375* 108.6	.1480* 100.9	.1558* 95.94	.1593 93.84	.1677 89.15	.1714 87.20	.1805 82.84	.1845 81.03	
647	HT-45	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	3.357* 65.48 33.34	3.328* 56.52 28.97	3.309 50.99 26.25	3.302 48.78 25.15	3.286 44.02 22.77	3.280 42.11 21.82	3.266 37.99 19.74	3.261 36.35 18.91	

S_u = 166 ksi
S_y = 159 ksi

Ti - 6 Al - 4 V - .2C

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
648	HT-44	Mechanical & Electropolish		80	1.0		L.E.V.	β M	.2010* 111.7	.2165* 103.7	.2281* 98.43	.2333* 96.25	.2458 91.36	.2513 89.33	.2648 84.79	.2708 82.91	
649	HT-44	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	2.157* 61.90 45.67	2.157* 52.96 39.08	2.157 47.49 35.05	2.157 45.32 33.44	2.157 40.64 29.99	2.157 38.78 28.61	2.157 34.77 25.66	2.157 33.18 24.48	

HT-45: 1600°F, 2 hrs., F.C. to 1100°F, A.C.

S_u = 172 ksi
S_y = 160 ksi

Ti - 6 Al - 4 V - 0.07 N_2 - 0.2 O_2 - 0.2 C

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING Effect of Stress Concentration																
650	HT-49	Mechanical & Electropolish		80	1.0		L.E.V.	β M	.0906* 137.2	.1029* 120.8	.1125* 110.4	.1170* 106.3	.1279 97.23	.1329 93.57	.1453 85.57	.1510 82.34	
651	HT-49	Mechanical & Electropolish		80	3.0		L.E.V.	β M	.3204* 63.63	.3702* 55.07	.4095 49.78	.4277 47.66	.4732 43.08	.4942 41.25	.5467 37.29	.5710 35.70	

Ti - 7 Al - 4 Mo

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
652	HT-50		167	80	1.0		S.E.V.	β M	.1437* 140.6	.1663* 121.5	.1842 109.7	.1924 105.0	.2131 94.87	.2226 90.80	.2465* 82.00	.2576* 78.48	

HT-49: 1700°F. 1 hr.. F.C. to 1100°F. A.C.
HT-50: 1725°F, 1 hr., W.Q.; 1200°F, 16 hrs.

$Ti - 7\ Al - 3\ Mo$

Composition: See Page 171
(*) Extrapolated Values

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES: $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									AXIAL (Completely Reversed) Effect of Heat Treatment								
653	HT-51	Mechanical Polish	60	600	1.0		Weibull	b	9.886*	9.061*	9.715*	8.954*	8.942	9.691	8.189	10.44	
								θ	93.26	84.63	79.08	76.80	71.76	69.70	65.12	63.25	
								X_o	72.17	66.96	61.48	60.94	56.96	54.22	52.72	48.20	
654	HT-52	Mechanical Polish	60	600	1.0		S.E.V.	β	.4897*	.5456*	.5885*	.6079	.6557	.6773	.7305	.7547	
								M	91.88	82.47	76.47	74.02	68.64	66.44	61.60	59.63	
									Effect of Test Temperature								
655	HT-51	Mechanical Polish	60	80	1.0		Weibull	b	1.562*	2.027*	1.977*	1.955	1.905	1.884	1.835	1.815*	
								θ	90.21	87.46	85.56	84.76	82.92	82.15	80.37	79.61	
								X_o	88.23	85.18	83.37	82.61	80.85	80.11	78.41	77.69	
656	HT-51	Mechanical Polish	60	400	1.0		Weibull	b	1.658*	1.658*	1.658*	1.658*	1.070	1.658	1.658	1.658	
								θ	93.20	86.78	82.55	80.79	76.81	75.22	71.55	70.03	
								X_o	90.64	84.39	80.27	78.57	75.17	73.15	69.58	68.10	
657	HT-51	Mechanical Polish	60	600	1.0		Weibull	b	9.886*	9.061*	9.715*	8.954*	8.942	9.691	8.189	10.44	
								θ	93.26	84.63	79.08	76.80	71.76	69.70	65.12	63.25	
								X_o	72.17	66.96	61.48	60.94	56.96	54.22	52.72	48.20	
658	HT-51	Mechanical Polish	60	800	1.0		S.E.V.	β	.5348*	.5601*	.5785*	.5866*	.6059	.6143	.6345	.6435	
								M	72.45	69.17	66.97	66.05	63.95	63.06	61.06	60.21	

HT-51: Aged 1560°F, in Argon, 0.5 hrs., A.C., 1020°F, 24 hrs., A.C.

HT-52: Annealed 1450°F, in Argon 1 hr., Slow Cool, 1 hr. at 100°F, heat to 1050°F, A.C.

S_u = 147 ksi
S_y = 133 ksi

Ti - 8 Al - 1 Mo - 1 V

Composition: See Page 171
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	LIFE IN CYCLES $1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed)																
	Effect of Stress Concentration																
659	HT-53		20	80	1.0		Normal	σ μ		5.955* 119.1	4.949 99.02	4.570 91.43	3.798 75.98	3.507 70.16	2.914* 58.31	2.691* 53.84	
660	HT-53		20	80	4.0		Weibull	b θ X_o	4.708* 78.89 55.06	4.523 44.06 31.20	4.251 29.32 21.20	4.543 24.61 17.40	4.250* 16.38 11.84	4.431* 13.75 9.807	4.541* 9.155 6.473	4.490* 7.683 5.454	
661	HT-53		20	550	1.0		S.E.V.	β M	.1111* 103.8	.1261 91.46	.1378 83.70	.1432 80.56	.1565 73.72	.1626 70.95	.1777 64.93	.1846* 62.49	
662	HT-53		20	550	4.0		Weibull	b θ X_o	8.086* 101.6 79.17	7.211* 45.93 36.78	7.427 26.36 20.97	7.788* 20.75 16.32	8.050* 11.91 9.290	7.417* 9.380 7.464			
	Effect of Test Temperature																
663	HT-53		20	80	1.0		Normal	σ μ		5.955* 119.1	4.949 99.02	4.570 91.43	3.798 75.98	3.507 70.16	2.914* 58.31	2.691* 53.84	
664	HT-53		20	550	1.0		S.E.V.	β M	.1111* 103.8	.1261 91.46	.1378 83.69	.1432 80.56	.1565 73.72	.1626 70.95	.1777 64.93	.1846* 62.49	

S_u = 147 ksi
S_y = 133 ksi

Ti - 8 Al - 1 Mo - 1 V (Cont'd)

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Test Temperature																
665	HT-53		20	80	4.0		Weibull	b θ X_o	4.708* 78.89 55.06	4.523 44.06 31.20	4.251 29.32 21.20	4.543 24.61 17.40	4.250* 16.38 11.84	4.431* 13.75 9.807	4.541* 9.155 6.473	4.490* 7.683 5.454	
666	HT-53		20	550	4.0		Weibull	b θ X_o	8.086* 101.6 79.17	7.211* 45.93 36.78	7.427 26.36 20.97	7.788* 20.75 16.32	8.050* 11.91 9.290	7.417* 9.380 7.464			

S_u = 131 ksi
S_y = 118 ksi

Ti - 3 Mn - 0.2 O_2

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Stress Concentration																
667	HT-54	Shaped Edges & Electropolish		80	1.0		Weibull	b θ X_o	8.947* 122.7 72.90	8.751 108.5 65.35	8.653 99.63 60.38	7.874 96.00 61.26	8.526 88.11 53.86	8.484 84.91 52.05	8.410 77.92 48.00	8.376 75.09 46.37	
668	HT-54	Shaped Edges & Electropolish		80	3.0		S.F.V.	β M	.2298* 60.55	.2685* 51.82	.2993 46.49	.3137 44.36	.3497 39.79	.3665 37.97	.4086 34.06	.4281 32.50	

HT-53: 1450°F 8 hrs., F.C., 1850°F 5 min. A.C., 1375°F, 15 min. A.C.
HT-54: 1250°F 1 hr., F.C. to 900°F, A.C.

S_u = 127 ksi
S_y = 110 ksi

Ti - 3 Mn - 0.07 N_2

Composition: See Page 171
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING Effect of Stress Concentration								
669	HT-54	Shaped Edges & Electropolish		80	1.0		Weibull	b	8.722*	8.654*	7.999	8.652	7.998	8.652	9.304	7.998	
								θ	105.3	98.65	94.24	92.41	88.28	86.57	82.71	81.09	
								X_o	81.03	76.06	74.16	71.26	69.47	66.76	62.48	63.81	
670	HT-54	Shaped Edges & Electropolish		80	3.0		Weibull	b	2.775*	2.917	2.885	2.873	2.832	2.773	2.882	2.851	
								θ	61.61	52.45	46.86	44.64	39.88	37.99	33.95	32.34	
								X_o	44.54	37.38	33.50	31.96	28.67	27.47	24.28	23.20	

S_u = 126 ksi
S_y = 111 ksi

Ti - 3 Mn - .2 C

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
671	HT-54	Shaped Edges & Electropolish		80	1.0		S.E.V.	β	.2117*	.2254	.2355	.2400	.2508	.2556	.2671	.2722	
								M	102.5	96.33	92.19	90.46	86.57	84.94	81.29	79.76	
672	HT-54	Shaped Edges & Electropolish		80	3.0		Weibull	b	2.978*	2.969*	2.901	2.874	3.012	2.990	2.944	2.924	
								θ	57.60	47.65	41.73	39.41	34.53	32.61	28.56	26.97	
								X_o	40.88	33.85	29.85	28.27	24.42	23.11	20.34	19.25	

S_u = 126-149 ksi
S_y = 111-125 ksi

Ti - 3 Mn COMPLEX

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Heat Treatment																
673	HT-55	Mechanical & Electropolish		80	3.0		S.E.V.	β M	.1159* 70.16	.1437 56.60	.1670 48.71	.1782 45.66	.2070 39.29	.2209 36.83	.2566 31.70	.2738 29.71	
674	HT-56	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	.9193* 63.56 54.39	1.235* 50.91 42.53	1.141 43.40 36.56	1.162 40.56 34.10	1.142 34.62 29.15	1.100 32.32 27.31	1.261 27.66 23.05	1.231 25.82 21.58	
675	HT-57	Mechanical & Electropolish		80	3.0		L.E.V.	β M	.2065* 68.70	.2441* 58.11	.2744 51.70	.2886 49.16	.3244 43.73	.3411 41.58	.3835 36.99	.4033 35.16	
676	HT-55	Shaped Edges & Electropolish		80	1.0		S.E.V.	β M	.1525* 100.9	.1683 91.46	.1804 85.37	.1858 82.88	.1991 77.36	.2051 75.09	.2197 70.09	.2263 68.04	
677	HT-57	Shaped Edges & Electropolish		80	1.0		Weibull	b θ X_o	2.997* 125.2 96.79	2.997* 112.4 86.87	2.997* 104.2 80.54	2.997 100.8 77.96	2.992 93.53 72.31	2.997 90.53 69.97	2.997 83.94 64.87	2.997 81.25 62.79	

HT-55: 1250°F, 1 hr., F.C. to 900°F, A.C.
HT-56: 1300°F, 1 hr., W.Q. to 1000°F, 2 hrs., A.C.
HT-57: 1500°F, 1 hr., W.Q.

S_u = 126-149 ksi
S_y = 111-125 ksi

T1 - 3 Mn COMPLEX (Cont'd)

Composition: See Page 171
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	ROTARY BEAM BENDING Effect of Heat Treatment																
678	HT-55	Mechanical & Electropolish		80	1.0		Weibull	b θ X_o	3.117* 108.2 89.32	3.158 95.88 78.94	3.108 88.07 72.70	3.072 84.91 70.21	2.973 77.99 64.81	2.867 75.18 62.81	3.002 69.07 57.32	2.908 66.58 55.52	
679	HT-56	Mechanical & Electropolish		80	1.0		L.E.V.	β M	.1141* 115.6	.1300* 101.5	.1424 92.67	.1481 89.10	.1622 81.34	.1687 78.21	.1848 71.39	.1922 68.64	
	Effect of Stress Concentration																
680	HT-55	Mechanical & Electropolish		80	1.0		Weibull	b θ X_o	3.117* 108.2 89.32	3.158 95.88 78.94	3.108 88.07 72.70	3.072 84.91 70.21	2.973 77.99 64.81	2.867 75.18 62.81	3.002 69.07 57.32	2.908 66.58 55.52	
681	HT-55	Mechanical & Electropolish		80	3.0		S.E.V.	β M	.1158* 70.16	.1436 56.59	.1670 48.71	.1782 45.66	.2070 39.29	.2209 36.83	.2566 31.70	.2738 29.71	

S_u = 126-149 ksi
S_y = 111-125 ksi

Ti - 3 Mn COMPLEX (Cont'd)

Composition: See Page 171
(*) Extrapolated Values

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	ROTARY BEAM BENDING — Effect of Stress Concentration																
682	HT-56	Mechanical & Electropolish		80	1.0		L.E.V.	β M	.1141* 115.6	.1300* 101.5	.1424 92.67	.1481 89.10	.1622 81.34	.1687 78.21	.1848 71.39	.1922 68.64	
683	HT-56	Mechanical & Electropolish		80	3.0		Weibull	b θ X_o	.9193* 63.56 54.39	1.235* 50.91 42.53	1.141 43.40 36.56	1.162 40.56 34.10	1.142 34.62 29.15	1.100 32.32 27.31	1.261 27.66 23.05	1.231 25.82 21.58	
	Effect of Surface Finish																
684	HT-55	Sh.E. & E.P.		80	1.0		S.E.V.	β M	.1525* 100.9	.1683 91.46	.1804 85.37	.1858 82.87	.1991 77.36	.2051 75.09	.2197 70.09	.2263 68.04	
685	HT-55	M.P. & E.P.		80	1.0		Weibull	b θ X_o	3.117* 108.2 89.32	3.158 95.88 78.94	3.108 88.07 72.70	3.072 84.91 70.21	2.973 77.99 64.81	2.867 75.18 62.81	3.002 69.07 57.32	2.908 66.58 55.52	

S_u = 147 ksi
S_y = 146 ksi

Ti - 3 Mn - .07 N_2 - .2 O_2 - .2 C

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Effect of Stress Concentration

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
686	HT-54	Shaped Edges & Electropolish		80	1.0		Weibull	b Θ X_o			.9852* 86.15 75.75	.9852* 84.82 74.58	.9852* 81.80 71.93	.9852 80.54 70.82	.9852 77.68 68.30	.9852 76.47 67.24	
687	HT-54	Shaped Edges & Electropolish		80	3.0		Normal	σ μ	3.914* 53.87	3.449* 47.48	3.158 43.46	3.040 41.84	2.783 38.31	2.679 36.88	2.453 33.76	2.361 32.50	

S_u = 130 ksi
S_y = 80 ksi

Ti - 4 Mn

Composition: See Page 171
(*) Extrapolated Values

ROTARY BEAM BENDING
Miscellaneous

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
688		M.P.		80	1.0		L.E.V.	β M	.2239* 94.38	.2588 81.68	.2863 73.82	.2990 70.68	.3309 63.88	.3456 61.16	.3823 55.28	.3993* 52.93	

S_u = 135 ksi
S_y = 125 ksi

Ti - 8 Mn

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING Effect of Heat Treatment																
689	HT-58	Polished - 8 RMS	166	80	1.0		S.E.V.	β M	.1310* 124.8	.1424* 114.9	.1509 108.4	.1547 105.7	.1639 99.79	.1681 97.33	.1781 91.85	.1826* 89.58	
690	HT-59	Polished - 8 RMS	166	80	1.0		L.E.V.	β M	.1437* 107.5	.1509* 102.4	.1561 99.03	.1583 97.60	.1638 94.34	.1662 92.98	.1719 89.88	.1745* 88.58	
691	HT-58	Polished - 8 RMS	166	80	3.0		Weibull	b θ X_o	1.379* 72.36 66.63	1.576* 59.86 54.79	1.769 52.44 47.69	1.797 49.53 44.99	1.534 43.34 39.72	1.685 40.94 37.34	1.408 35.83 32.96	1.765* 33.86 30.80	
692	HT-59	Polished - 8 RMS	166	80	3.0		L.E.V.	β M	.3778* 72.78	.4672* 58.87	.5419 50.75	.5776 47.61	.6700 41.05	.7142* 38.50	.8284* 33.20	.8831* 31.14	

HT-58: Vacuum Annealed at 820°C, 19 ppm H_2
HT-59: Hydrogenated at 820°C, 368 ppm H_2

S_u = 135 ksi
S_y = 125 ksi

Ti - 8 Mn (Cont'd)

Composition: See Page 171
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									ROTARY BEAM BENDING — Effect of Stress Concentration								
693	HT-58	Polished - 8 RMS	166	80	1.0		S.E.V.	β M	.1310* 124.8	.1424* 114.9	.1509 108.4	.1547 105.7	.1639 99.79	.1681 97.33	.1781 91.85	.1826* 89.58	
694	HT-58	Polished - 8 RMS	166	80	3.0		Weibull	b θ X_o	1.379* 72.36 66.63	1.576* 59.86 54.79	1.769 52.44 47.69	1.797 49.53 44.99	1.534 43.34 39.72	1.685 40.94 37.34	1.408 35.83 32.96	1.765* 33.86 30.80	
695	HT-59	Polished - 8 RMS	166	80	1.0		L.E.V.	S M	.1437* 107.5	.1509* 102.4	.1561 99.03	.1583 97.60	.1638 94.34	.1662 92.98	.1719 89.88	.1745* 88.58	
696	HT-59	Polished - 8 RMS	166	80	3.0		L.E.V.	β M	.3778* 72.78	.4672* 58.87	.5419 50.75	.5776 47.61	.6700 41.04	.7142* 38.50	.8284* 33.20	.8831* 31.14	

Table column group headings: TEST CONDITIONS (Heat Treat through Other); FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES ($1x10^3$ through $1x10^8$).

Ti - 30 Mo

Composition: See Page 172
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	ROTARY BEAM BENDING — Effect of Stress Concentration																
697	HT-60		100	80	2.5	Machine Notch	Weibull	b θ X_o	3.814* 55.49 40.89	3.646* 43.56 32.50	3.817* 36.79 27.10	3.720 34.20 25.38	3.681 28.88 21.49	3.838* 26.85 19.75	3.711* 22.68 16.84	3.663* 21.08 15.71	
698	HT-60		100	80	3.0	Machine Notch	Weibull	b θ X_o	1.175* 68.51 54.41	1.392 46.20 35.62	.9191 34.67 28.12	1.081 30.77 24.68	1.156 23.31 18.55	1.256* 20.71 16.29	1.345* 15.70 12.19	1.375* 13.94 10.77	
	Effect of Surface Finish																
699	HT-3	Hand Finish	100	80	1.0		L.E.V.	β M	.1202* 97.72	.1333* 88.14	.1432* 82.00	.1478 79.50	.1588 73.96	.1638 71.70	.1761 66.71	.1817 64.67	
700	HT-3	Ground	100	80	1.0		S.E.V.	β M	.1747* 88.06	.2035* 75.57	.2265* 67.90	.2372 64.84	.2640 58.26	.2764 55.64	.3077 50.00	.3222 47.74	
701	HT-3	Notch Rolled	100	80	3.0		L.E.V.	β M	.2181* 131.6	.2503* 114.6	.2756 104.1	.2873 99.88	.3164 90.70	.3299* 87.01	.3633* 79.01	.3787* 75.80	
702	HT-3	Notch Machined	100	80	3.0		Weibull	b θ X_o	1.175* 68.51 54.41	1.392 46.20 35.62	.9191 34.67 28.12	1.081 30.77 24.68	1.156 23.31 18.55	1.256* 20.71 16.29	1.345* 15.70 12.19	1.375* 13.94 10.77	

HT-60: Annealed 450°F, 0.5 hrs., Shot peened with .010 Steel Shot to Almen #10

S_u = 174-203 ksi
S_y = 156-186 ksi

Ti - 13 V - 11 Cr - 3 Al

Composition: See Page 172
(*) Extrapolated Values

FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS

AXIAL (Completely Reversed)
Effect of Heat Treatment

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
703	HT-61	Ground Edges	60	75	1.0	Sheet Specimens	S.E.V.	β	.1544*	.2754*	.4127	.4912	.7360*	.8760*			
								M	135.0	75.72	50.54	42.46	28.34	23.81			
704	HT-62	Ground Edges	60	75	1.0	Sheet Specimens	Weibull	b	4.531*	4.474*	4.342	4.301	4.217	4.185	4.119*	4.094*	
								θ	77.02	59.79	50.09	46.41	38.88	36.02	30.18	27.96	
								X_o	42.07	32.95	28.16	26.25	22.27	20.73	17.53	16.30	
705	HT-61	Ground Edges	60	600	1.0	Sheet Specimens	Weibull	b	2.142*	2.142*	2.142	2.142	2.142	2.141	2.164	2.173	
								θ	56.74	53.63	51.56	50.69	48.74	47.92	46.07	45.29	
								X_o	46.39	43.85	4[illegible].15	41.44	39.84	39.18	37.61	36.96	
706	HT-62	Ground Edges	60	600	1.0	Sheet Specimens	L.E.V.	β	.4171*	.4699*	.5107	.5293	.5752	.5962	.6480	.6716	
								M	69.46	61.66	56.74	54.74	50.37	48.59	44.71	43.14	
707	HT-61	Ground Edges	60	800	1.0	Sheet Specimens	Weibull	b	2.558*	2.528*	2.506	2.498	2.478	2.469	2.450	2.442	
								θ	60.63	58.16	56.50	55.80	54.20	53.53	52.00	51.35	
								X_o	48.95	47.05	45.77	45.22	43.99	43.46	42.27	41.77	
708	HT-62	Ground Edges	60	800	1.0	Sheet Specimens	S.E.V.	β	.1240*	.1384*	.1495	.1545	.1669	.1725	.1863	.1926*	
								M	68.76	61.60	57.04	55.18	51.10	49.43	45.78	44.28	

HT-61: Solution H.T. 1450°F, 30 min., A.C., Aged 900°F, 12 hrs.
HT-62: Solution H.T. 1450°F, 30 min., A.C.

S_u = 174-203 ksi
S_y = 156-186 ksi

Ti - 13 V - 11 Cr - 3 Al (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
709	HT-62	Ground Edges	60	75	1.0	Sheet Specimens	Weibull	b θ X_o	4.531* 77.02 42.07	4.474* 59.79 32.95	4.342 50.09 28.16	4.301 46.41 26.25	4.217 38.88 22.27	4.185 36.02 20.73	4.119* 30.18 17.53	4.094* 27.96 16.30	
710	HT-62	Ground Edges	60	75	3.0	Sheet Specimens	Weibull	b θ X_o	3.841* 29.23 19.57	3.598* 26.28 18.04	3.778 24.40 16.44	3.768 23.63 15.94	3.746 21.94 14.83	3.737 21.25 14.38	3.717 19.73 13.38	3.709 19.10 12.96	
711	HT-63	As Machined	60	75	1.0	Lathe Turned and Bored Bar	Weibull	b θ X_o	1.785* 101.7 81.18	1.848* 89.85 71.31	1.658 82.26 66.31	1.673 79.24 63.79	1.711 72.64 58.31	1.725 69.97 56.10	1.757 64.14 51.29	1.770 61.78 49.36	
712	HT-63	As Machined	60	75	3.0	Lathe Turned and Bored Bar	Normal	σ μ	2.749* 39.56	2.625* 37.79	2.543 36.59	2.508 36.09	2.429 34.95	2.395 34.47	2.320 33.39	2.288 32.93	
713	HT-63	As Machined	60	600	1.0	Lathe Turned and Bored Bar	Weibull	b θ X_o	1.050* 102.6 93.81	.6147* 91.03 84.83	.8082 84.41 78.07	.8706 81.67 75.32	.9993 75.62 69.30	1.050 73.15 66.86	.6426 67.15 62.52	.7471* 65.02 60.30	
714	HT-63	As Machined	60	600	3.0	Lathe Turned and Bored Bar	Weibull	b θ X_o	1.504* 44.70 35.65	1.513* 42.64 33.97	1.521 41.26 32.84	1.523 40.67 32.37	1.524 39.35 31.32	1.524 38.70 30.87	1.524 37.53 29.87	1.524 37.00 29.44	

HT-63: Solution H.T. 1400°F, 30 min., A.C., Aged 900°F, 72 hrs. in Argon

S_u = 174-203 ksi
S_y = 156-186 ksi

Ti - 13 V - 11 Cr - 3 Al (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
	AXIAL (Completely Reversed) — Effect of Stress Concentration																
715	HT-63	Ground Edges	60	75	1.0	Sheet Specimens	S.E.V.	β M	.2773* 107.1	.3172* 93.69	.3485 85.28	.3629 81.90	.3986 74.55	.4151 71.59	.4560 65.17	.4749 62.59	
716	HT-63	Ground Edges	60	75	3.0	Sheet Specimens	Weibull	b θ X_o	5.290* 46.86 27.06	5.271* 43.26 25.04	5.259 40.91 23.72	5.242 39.94 23.20	5.198 37.77 22.05	5.179 36.88 21.57	5.138 34.88 20.50	5.122 34.05 20.05	
	Effect of Test Temperature																
717	HT-61	Ground Edges	60	75	1.0	Sheet Specimens	S.E.V.	β M	.1544* 135.0	.2754* 75.72	.4127 50.54	.4912 42.46	.7360* 28.34	.8760* 23.81			
718	HT-61	Ground Edges	60	600	1.0	Sheet Specimens	Weibull	b θ X_o	2.142* 56.74 46.39	2.142* 53.63 43.85	2.142 51.56 42.15	2.142 50.69 41.44	2.142 48.74 39.84	2.141 47.92 39.18	2.164 46.07 37.61	2.173 45.29 36.96	
719	HT-61	Ground Edges	60	800	1.0	Sheet Specimens	Weibull	b θ X_o	2.558* 60.63 48.94	2.528* 58.16 47.05	2.506 56.50 45.77	2.498 55.80 45.22	2.478 54.20 43.99	2.469 53.53 43.46	2.450 52.00 42.27	2.442 51.35 41.77	

S_u = 174-203 ksi
S_y = 156-186 ksi

Ti - 13 V - 11 Cr - 3 Al (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
									AXIAL (Completely Reversed) Effect of Test Temperature								
720	HT-62	Ground Edges	60	75	1.0	Sheet Specimens	Weibull	b θ X_o	4.531* 77.02 42.07	4.474* 59.79 32.95	4.342 50.09 28.16	4.301 46.41 26.25	4.217 38.88 22.27	4.185 36.02 20.73	4.119* 30.18 17.53	4.094* 27.96 16.30	
721	HT-62	Ground Edges	60	600	1.0	Sheet Specimens	L.E.V.	β M	.4171* 69.46	.4699* 61.66	.5107 56.74	.5293 54.74	.5752 50.37	.5962 48.59	.6480 44.71	.6716 43.14	
722	HT-62	Ground Edges	60	800	1.0	Sheet Specimens	S.E.V.	β M	.1240* 68.76	.1384* 61.60	.1495 57.04	.1545 55.18	.1669 51.10	.1725 49.43	.1863 45.78	.1926* 44.28	
723	HT-63	As Machined	60	75	1.0	Lathe Turned and Bored Bar	Weibull	b θ X_o	1.785* 101.7 81.18	1.848* 89.85 71.31	1.658 82.26 66.31	1.673 79.24 63.79	1.711 72.64 58.31	1.725 69.97 56.10	1.757 64.14 51.29	1.770 61.78 49.35	
724	HT-63	As Machined	60	600	1.0	Lathe Turned and Bored Bar	Weibull	b θ X_o	1.050* 102.6 93.81	.6147* 91.03 84.83	.8082 84.41 78.07	.8706 81.67 75.32	.9993 75.62 69.30	1.050 73.15 66.86	.6426 67.15 62.52	.7471* 65.02 60.30	
725	HT-63	As Machined	60	800	1.0	Lathe Turned and Bored Bar	S.E.V.	β M	.2773* 107.1	.3172* 93.69	.3485 85.28	.3629 81.90	.3986 74.55	.4151 71.59	.4560 65.17	.4749 62.59	

S_u = 174-203 ksi
S_y = 156-186 ksi

Ti - 13 V - 11 Cr - 3 Al (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
726	HT-63	As Machined	60	75	3.0	Lathe Turned and Bored Bar	Normal	σ	2.749*	2.625*	2.543	2.508	2.429	2.395	2.320	2.288	
								μ	39.56	37.79	36.59	36.09	34.95	34.47	33.39	32.93	
727	HT-63	As Machined	60	600	3.0	Lathe Turned and Bored Bar	Weibull	b	1.504*	1.513*	1.521	1.523	1.524	1.524	1.524	1.524	
								θ	44.70	42.64	41.26	40.67	39.35	38.70	37.53	37.00	
								X_o	35.65	33.97	32.84	32.37	31.32	30.87	29.87	29.44	
728	HT-63	As Machined	60	800	3.0	Lathe Turned and Bored Bar	Weibull	b	5.290*	5.271*	5.259	5.242	5.198	5.179	5.138	5.122	
								θ	46.86	43.26	40.91	39.94	37.77	36.88	34.88	34.05	
								X_o	27.06	25.04	23.72	23.20	22.05	21.57	20.50	20.05	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn

Composition: See Page 172
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
							AXIAL (Completely Reversed) Effect of Test Temperature										
729	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	80	1.0	.020 in. Sheet	Normal	σ μ	19.37 113.0	14.95 87.24	12.47 72.79	11.54 67.33	9.629 56.18	8.907 51.97	7.432 43.36	6.875* 40.11	
730			30	80	2.8		L.E.V.	β M	.1070* 65.86	.1401 50.31	.1691 41.68	.1834 38.43	.2214 31.84	.2401 29.36	.2899* 24.32	.3144* 22.43	
731			30	400	1.0		S.E.V.	β M	.0725* 114.3	.1025 80.88	.1306 63.49	.1450 57.21	.1847 44.91	.2050 40.47	.2611 31.77	.2898* 28.62	
732			30	400	2.8		Normal	σ μ	9.378* 68.14	6.805 49.45	5.439 39.52	4.939 35.88	3.947 28.68	3.584 26.04	2.864* 20.81	2.601* 18.90	
733			30	600	1.0		L.E.V.	β M	.0819* 68.65	.1004 56.00	.1158 48.56	.1231 45.68	.1420 39.61	.1510 37.26	.1741 32.31	.1851* 30.39	
734			30	600	2.8		Weibull	b θ X_o	2.288* 64.26 43.18	2.288 47.78 32.11	2.288 38.84 26.10	2.241 35.51 24.02	2.286 28.87 19.41	2.249 26.40 17.83	2.176 21.45 14.64	2.292* 19.63 13.18	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
									AXIAL (Completely Reversed) Effect of Stress Concentration								
735	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	800	1.0	.020 in. Sheet	Weibull	b	3.448*	3.394	3.364	3.353	3.330	3.324	3.324	3.324*	
								θ	90.71	67.90	55.45	50.82	41.51	38.04	31.07	28.48	
								X_o	38.79	29.48	24.27	22.31	18.34	16.83	13.75	12.60	
736			30	800	2.8		Weibull	b	3.433*	3.382	3.364	3.364	3.303	3.269	3.204*	3.181*	
								θ	67.80	46.28	35.44	31.59	24.19	21.56	16.51	14.71	
								X_o	29.44	20.39	15.69	13.99	10.89	9.799	7.633	6.845	
737			30	900	1.0		Weibull	b	4.748*	4.690	4.654	4.623	4.484	4.456	4.396	4.372*	
								θ	74.21	60.44	52.36	49.22	42.64	40.08	34.72	32.64	
								X_o	34.65	28.53	24.88	23.53	20.90	19.75	17.29	16.33	
738			30	900	2.8		Normal	σ	7.876*	5.714	4.565	4.145	3.312	3.007	2.403*	2.181*	
								μ	52.21	37.88	30.27	27.48	21.96	19.93	15.93	14.46	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
									AXIAL (Completely Reversed) Effect of Stress Concentration								
739	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	80	1.0	.063 in. Sheet	Normal	σ μ	20.62* 108.3	16.81 88.34	14.57 76.56	13.70 71.99	11.87 62.40	11.16 58.67	9.678 50.85	9.100* 47.81	
740	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	80	2.8	.063 in. Sheet	Normal	σ μ	9.099* 66.81	7.465 54.81	6.500 47.72	6.124 44.96	5.332 39.15	5.024 36.89	4.375 32.12	4.121 30.26	
741	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	400	1.0	.063 in. Sheet	WEIBULL	b θ X_o	1.863* 107.5 74.31	1.826 80.62 55.96	1.829 65.91 45.73	1.854 60.44 41.80	1.760 49.38 34.57	1.779 45.28 31.62	1.817 37.02 25.73	1.831* 33.95 23.55	
742	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	400	2.8	.063 in. Sheet	Weibull	b θ X_o	3.623* 73.45 32.44	3.581 57.69 25.76	3.557 48.73 21.90	3.548 45.32 20.41	3.528 38.28 17.33	3.523 35.60 16.14	3.523 30.07 13.63	3.523* 27.97 12.68	
743	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	600	1.0	.063 in. Sheet	Weibull	b θ X_o	3.593* 103.1 63.85	3.593 80.40 49.75	3.711 67.54 41.15	3.667 62.65 38.39	3.740 52.63 31.94	3.705 48.82 29.77	3.635 41.00 25.23	3.609* 38.03 23.48	
744	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	600	2.8	.063 in. Sheet	Weibull	b θ X_o	2.746* 80.17 52.90	2.746 58.18 38.39	2.746 46.50 30.68	2.746 42.23 27.86	2.746 33.75 22.27	2.746 30.65 20.22	2.746 24.49 16.16	2.746* 22.24 14.67	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	TEST CONDITIONS: Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
745	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	800	1.0	.063 in. Sheet	L.E.V.	β	.1023*	.1286	.1509	.1617	.1897	.2032	.2385	.2555*	
								M	83.18	66.18	56.40	52.65	44.87	41.89	35.70	33.33	
746			30	800	2.8		Weibull	b	1.779*	1.779	1.779	1.759	1.786	1.754	1.689	1.782*	
								θ	67.11	48.86	39.14	35.56	28.4[illegible]	25.89	20.72	18.85	
								X_o	43.28	31.51	25.24	23.01	18.[illegible]	16.76	13.56	12.15	
747			30	900	1.0		Weibull	b	1.206*	1.265	1.297	1.309	1.312	1.312	1.312	1.312	
								θ	80.72	62.37	52.07	48.18	40.21	37.19	31.04	28.71	
								X_o	56.92	43.65	36.28	33.51	27.96	25.86	21.58	19.96	
748			30	900	2.8		Weibull	b	1.396*	1.476	1.515	1.529	1.552	1.552	1.552	1.552	
								θ	58.83	42.31	33.60	30.42	24.15	21.86	17.35	15.70	
								X_o	39.49	38.04	22.11	19.97	15.79	14.29	11.34	10.27	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
749	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	80	1.0	.125 in. Sheet	L.E.V.	β	.0867*	.1157	.1415	.1543	.1888	.2059	.2519	.2748	
								M	118.9	89.13	72.86	66.80	54.61	50.07	40.93	37.52	
750			30	80	2.8		Weibull	b	2.396*	2.396*	2.396*	2.396	2.396	2.396	2.522*	2.478*	
								θ	72.31	55.72	46.43	42.93	35.77	33.07	27.58	25.49	
								X_o	49.83	38.39	31.99	29.58	24.65	22.79	18.69	17.38	
751			30	400	1.0		L.E.V.	β	.0863	.1167	.1442	.1580	.1951	.2137	.2640	.2892*	
								M	125.9	93.13	75.39	68.83	55.72	50.88	41.19	37.61	
752			30	400	2.8		Weibull	b	1.866*	1.181	1.249	1.329	1.410	1.375	1.465*	1.395*	
								θ	80.75	55.93	43.45	38.99	30.30	27.16	21.11	18.92	
								X_o	65.68	47.76	36.97	33.03	25.53	22.94	17.72	15.96	
753			30	600	1.0		Weibull	b	.9699*	1.183	1.797	.9807	.9301	1.307	.9532	1.157*	
								θ	100.7	76.63	63.72	57.98	47.78	44.19	36.25	33.44	
								X_o	86.58	65.00	51.13	49.81	41.14	37.12	31.18	28.42	
754			30	600	2.8		L.E.V.	β	.2243*	.2836*	.3341	.3585	.4224	.4533	.5340*	.5730*	
								M	49.82	39.41	33.45	31.17	26.46	24.66	20.93	19.51	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Stress Concentration

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
755	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	800	1.0	.125 in. Sheet	Weibull	b	2.407*	2.381	2.406	2.378	2.424	2.404	2.363	2.349	
								θ	106.7	77.42	61.87	56.16	44.89	40.76	32.56	29.55	
								X_o	60.86	44.38	35.29	32.21	25.51	23.25	18.73	17.05	
756			30	800	2.8		Weibull	b	3.188*	3.263	3.261	3.262	3.262	3.137	3.199*	3.157*	
								θ	74.40	53.45	42.41	38.38	30.45	27.56	21.87	19.79	
								X_o	41.80	29.62	23.51	21.28	16.88	15.62	12.26	11.18	
757			30	900	1.0		L.E.V.	β	.5505*	.8293	.1104	.1249	.1663	.1882	.2506*	.2835*	
								M	76.66	50.89	38.21	33.78	25.37	22.42	16.84	14.88	
758			30	900	2.8		Weibull	b	1.838*	1.945*	1.820*	1.841	1.884	1.900	1.933*	1.946*	
								θ	43.02	34.18	29.07	27.12	23.08	21.54	18.33	17.10	
								X_o	37.44	25.48	21.96	20.44	17.32	16.13	13.68	12.75	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd.)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
759	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	80	1.0	.020 in. Sheet	Normal	σ μ	19.37* 113.0	14.95 87.24	12.47 72.79	11.54 67.33	9.629 56.18	8.907 51.97	7.432 43.36	6.875* 40.11	
760	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	400	1.0	.020 in. Sheet	S.E.V.	β M	.0725* 114.3	.1025 80.88	.1306 63.49	.1450 57.21	.1847 44.91	.2050 40.47	.2611 31.77	.2898* 28.62	
761	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	600	1.0	.020 in. Sheet	L.E.V.	β M	.0819* 68.65	.1004 56.00	.1158 48.56	.1231 45.68	.1420 39.61	.1510 37.26	.1741 32.31	.1851* 30.39	
762	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	800	1.0	.020 in. Sheet	Weibull	b θ X_o	3.448* 90.71 38.79	3.394 67.90 29.48	3.364 55.45 24.27	3.353 50.82 22.31	3.330 41.51 18.34	3.324 38.04 16.83	3.324 31.07 13.75	3.324* 28.48 12.60	
763	1400°F, 20 min., 990°F, 6 hrs.	Ground and Milled Edges	30	900	1.0	.020 in. Sheet	Weibull	b θ X_o	4.748* 74.21 34.65	4.690 60.44 28.53	4.654 52.36 24.88	4.623 49.22 23.53	4.484 42.64 20.90	4.456 40.08 19.75	4.396 34.72 17.29	4.372* 32.64 16.33	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

+Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	AXIAL (Completely Reversed) Effect of Test Temperature																
764	1400°F, 20 min., 990°F, 6 hrs.	Milled Edges	30	80	2.8	.020 in. Sheet	L.E.V.	β M	.1070* 65.86	.1401 50.31	.1691 41.68	.1834 38.43	.2214 31.84	.2401 29.36	.2899* 24.32	.3144* 22.43	
765	1400°F, 20 min., 990°F, 6 hrs.	Milled Edges	30	400	2.8	.020 in. Sheet	Normal	σ μ	9.378* 68.14	6.805 49.45	5.439 39.52	4.939 35.88	3.947 28.68	3.584 26.04	2.864* 20.81	2.601* 18.90	
766	1400°F, 20 min., 990°F, 6 hrs.	Milled Edges	30	600	2.8	.020 in. Sheet	Weibull	b θ X_o	2.288* 64.26 43.18	2.288 47.78 32.11	2.288 38.84 26.10	2.241 35.51 24.02	2.286 28.87 19.41	2.249 26.40 17.83	2.176 21.45 14.64	2.292* 19.63 13.18	
767	1400°F, 20 min., 990°F, 6 hrs.	Milled Edges	30	800	2.8	.020 in. Sheet	Weibull	b θ X_o	3.433* 67.80 29.44	3.382 46.28 20.39	3.364 35.44 15.69	3.364 31.59 13.99	3.303 24.19 10.89	3.269 21.56 9.799	3.204* 16.51 7.633	3.181* 14.71 6.845	
768	1400°F, 20 min., 990°F, 6 hrs.	Milled Edges	30	900	2.8	.020 in. Sheet	Normal	σ μ	7.876* 52.21	5.714 37.88	4.565 30.27	4.145 27.48	3.312 21.96	3.007 19.93	2.403* 15.93	2.181* 14.46	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
769	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	80	1.0	.063 in. Sheet	Normal	σ	20.62*	16.81	14.57	13.70	11.87	11.16	9.678	9.100*	
								μ	108.3	88.34	76.56	71.99	62.40	58.67	50.85	47.81	
770	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	400	1.0	.063 in. Sheet	Weibull	b	1.863*	1.826	1.829	1.854	1.760	1.779	1.817	1.831*	
								θ	107.5	80.62	65.91	60.44	49.38	45.28	37.02	33.95	
								X_o	74.31	55.96	45.73	41.80	34.57	31.62	25.73	23.55	
771	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	600	1.0	.063 in. Sheet	Weibull	b	3.593*	3.593	3.711	3.667	3.740	3.705	3.635	3.609*	
								θ	103.1	80.40	67.54	62.65	52.63	48.82	41.00	38.03	
								X_o	63.85	49.75	41.15	38.39	31.94	29.77	25.23	23.48	
772	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	800	1.0	.063 in. Sheet	L.E.V.	S	.1023*	.1286	.1509	.1617	.1897	.2032	.2385	.2555*	
								M	83.18	66.18	56.40	52.65	44.87	41.89	35.70	33.33	
773	1410°F, 25 min., 990°F, 4 hrs.	Ground and Milled Edges	30	900	1.0	.063 in. Sheet	Weibull	b	1.206*	1.265	1.297	1.309	1.312	1.312	1.312	1.312	
								θ	80.72	62.37	52.07	48.18	40.21	37.19	31.04	28.71	
								X_o	56.92	43.65	36.28	33.51	27.96	25.86	21.58	19.96	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
774	1410°F, 25 min., 990°F, 4 hrs.	Milled Edges	30	80	2.8	.063 in. Sheet	Normal	σ	9.099*	7.465	6.500	6.124	5.332	5.024	4.375	4.121	
								μ	66.81	54.81	47.72	44.96	39.15	36.89	32.12	30.26	
775			30	400	2.8		Weibull	b	3.623*	3.581	3.557	3.548	3.528	3.523	3.523	3.523*	
								θ	73.45	57.69	48.73	45.32	38.28	35.60	30.07	27.97	
								X_o	32.44	25.76	21.90	20.41	17.33	16.14	13.63	12.68	
776			30	600	2.8		Weibull	b	2.746*	2.746	2.746	2.746	2.746	2.746	2.746	2.746*	
								θ	80.17	58.18	46.50	42.23	33.75	30.65	24.49	22.24	
								X_o	52.90	38.39	30.68	27.86	22.27	20.22	16.16	14.67	
777			30	800	2.8		Weibull	b	1.779*	1.779	1.779	1.759	1.786	1.754	1.689	1.782*	
								θ	67.11	48.86	39.14	35.56	28.49	25.89	20.72	18.85	
								X_o	43.28	31.51	25.24	23.01	18.35	16.76	13.56	12.15	
778			30	900	2.8		Weibull	b	1.396*	1.476	1.515	1.529	1.552	1.552	1.552	1.552*	
								θ	58.83	42.31	33.60	30.42	24.15	21.86	17.35	15.70	
								X_o	39.49	28.04	22.11	19.97	15.79	14.29	11.34	10.27	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
779	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	80	1.0	.125 in. Sheet	L.E.V.	β M	.0867* 118.9	.1157 89.13	.1415 72.86	.1543 66.80	.1888 54.61	.2059 50.07	.2519 40.93	.2748 37.52	
780	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	400	1.0	.125 in. Sheet	L.E.V.	β M	.0863 125.9	.1167 93.13	.1442 75.39	.1580 68.83	.1951 55.72	.2137 50.88	.2640 41.19	.2892* 37.61	
781	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	600	1.0	.125 in. Sheet	Weibull	b θ X_o	.9699* 100.7 86.58	1.183 76.63 65.00	1.797 63.72 51.13	.9807 57.98 49.81	.9301 47.78 41.14	1.307 44.19 37.12	.9532 36.25 31.18	1.157* 33.44 28.42	
782	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	800	1.0	.125 in. Sheet	Weibull	b θ X_o	2.407* 106.7 60.86	2.381 77.42 44.38	2.406 61.87 35.29	2.378 56.16 32.21	2.424 44.89 25.51	2.404 40.76 23.25	2.363 32.56 18.73	2.349 29.55 17.05	
783	1410°F, 30 min., 975°F, 4 hrs.	Ground and Milled Edges	30	900	1.0	.125 in. Sheet	L.E.V.	β M	.5505* 76.66	.8293 50.89	.1104 38.21	.1249 33.78	.1663 25.37	.1882 22.42	.2506* 16.84	.2835* 14.88	

S_u = 107-186 ksi
S_y = 78-173 ksi

Ti - 16 V - 2.5 Sn (Cont'd)

Composition: See Page 172
(*) Extrapolated Values

AXIAL (Completely Reversed)
Effect of Test Temperature

Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
784	1410°F, 30 min., 975°F, 4 hrs.	Milled Edges	30	80	2.8	.125 in. Sheet	Weibull	b	2.396*	2.396*	2.396*	2.396	2.396	2.396	2.522*	2.478*	
								θ	72.31	55.72	46.43	42.93	35.77	33.07	27.58	25.49	
								X_o	49.83	38.39	31.99	29.58	24.65	22.79	18.69	17.38	
785	1410°F, 30 min., 975°F, 4 hrs.	Milled Edges	30	400	2.8	.125 in. Sheet	Weibull	b	1.866*	1.181	1.249	1.329	1.410	1.375	1.465*	1.395*	
								θ	80.75	55.93	43.45	38.99	30.30	27.16	21.11	18.92	
								X_o	65.68	47.76	36.97	33.03	25.53	22.94	17.72	15.96	
786	1410°F, 30 min., 975°F, 4 hrs.	Milled Edges	30	600	2.8	.125 in. Sheet	L.E.V.	β	.2243*	.2836*	.3341	.3585	.4224	.4533	.5340*	.5730*	
								M	49.82	39.41	33.45	31.17	26.46	24.66	20.93	19.51	
787	1410°F, 30 min., 975°F, 4 hrs.	Milled Edges	30	800	2.8	.125 in. Sheet	Weibull	b	3.188*	3.263	3.261	3.262	3.262	3.137	3.199*	3.157*	
								θ	74.40	53.45	42.41	38.38	30.45	27.56	21.87	19.79	
								X_o	41.80	29.62	23.51	21.28	16.88	15.62	12.26	11.18	
788	1410°F, 30 min., 975°F, 4 hrs.	Milled Edges	30	900	2.8	.125 in. Sheet	Weibull	b	1.838*	1.945*	1.820*	1.841	1.884	1.900	1.933*	1.946*	
								θ	43.02	34.18	29.07	27.12	23.08	21.54	18.33	17.10	
								X_o	32.44	25.48	21.96	20.44	17.32	16.13	13.68	12.75	

A-1.5.7 Other Non-Ferrous Alloys

BERILCO #25

Composition: See Page 172
(*) Extrapolated Values

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
	TEST CONDITIONS						**FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES**										
	ROTARY BEAM BENDING — Miscellaneous																
789	HT-64		200	80	1.0	R.R. Moore	Weibull	b	5.740*	6.119*	5.640*	5.850*	5.817	5.787	5.685	5.865	5.899*
								θ	89.01	74.41	65.64	62.19	54.87	51.99	45.86	43.46	36.33
								X_o	51.53	41.37	38.40	35.60	31.51	29.96	26.71	24.83	20.68

COMMERCIALLY PURE LEAD

Composition: See Page 172
(*) Extrapolated Values

CANTILEVER BEAM BENDING (Completely Reversed)
Effect of Impurities

Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
790				80	1.0	99.995% Lead	Weibull	b	3.867*	3.867	3.867*	3.867*					
								θ	3.755	1.440	.7375	.5527					
								X_o	3.492	1.339	.6857	.5139					
791				80	1.0	99.915% Lead	Weibull	b	.6869*	.6869	.6869*	.9777*					
								θ	3.786	1.920	1.194	.9775					
								X_o	3.548	1.799	1.119	.9050					

HT-64: Age hardened 600°F, 3 hrs., A.C.

S_u = 139 ksi
S_y = 111 ksi

0.5 Ti MOLYBDENUM

Composition: See Page 172
(*) Extrapolated Values

Code No.	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS										
									LIFE IN CYCLES								
	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	$1x10^3$	$1x10^4$	$5x10^4$	$1x10^5$	$5x10^5$	$1x10^6$	$5x10^6$	$1x10^7$	$1x10^8$
PLATE BENDING (Completely Reversed) Miscellaneous																	
792		Ground Edges		80	1.0	Hot Rolled	Normal	σ μ		4.483* 137.0	4.095* 125.1	3.939 120.3	3.598 109.9	3.460 105.7	3.161 96.59	3.040* 92.90	2.671* 81.62

S_u = 93-103 ksi
S_y = 87-96 ksi

COMMERCIALLY PURE TANTALUM

Composition: See Page 172
(*) Extrapolated Values

←Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10^3	1x10^4	5x10^4	1x10^5	5x10^5	1x10^6	5x10^6	1x10^7	1x10^8
	TEST CONDITIONS						FATIGUE STRENGTH DISTRIBUTIONS AND THEIR PARAMETERS — LIFE IN CYCLES										
	AXIAL (Completely Reversed) Effect of Heat Treatment																
793	Annealed 1650°C	Polished		80	1.0		S.E.V.	β M		.7785* 101.1	.9551* 82.43	1.043* 75.47	1.280 61.51	1.398 56.32	1.715 45.89	1.873* 42.02	2.510* 31.36
794	Annealed 2320°C	Polished		80	1.0		L.E.V.	β M	.5483* 56.98	.6135 50.93	.6636 47.08	.6864 45.52	.7425 42.08	.7680 40.68	.8307 37.61	.8593* 36.36	.9614* 32.50
795		Polished		80	1.0		S.E.V.	β M			.2189* 88.54	.2357 82.26	.2796 69.34	.3009 64.42	.3570* 54.30	.3843* 50.45	
796	HT-65	Polished		80	1.0	295 ppm H_2	Weibull	b θ X_o	.9122 36.33 27.88	.9571 26.31 20.00	.9627 20.96 15.91	.9627 19.00 14.43	.9627 15.14 11.49	.9627 13.72 10.42	.9627* 10.93 8.303	.9627* 9.915 7.528	.9627* 7.161 5.437
	Effect of Test Temperature																
797	Annealed 1650°C	Polished		80	1.0		S.E.V.	β M		.7785* 101.1	.9551* 82.43	1.043* 75.47	1.280 61.51	1.398 56.32	1.715 45.89	1.873* 42.02	2.510* 31.36
798	Annealed 1650°C	Polished		550	1.0		S.E.V.	β M	.3173* 100.0	.3780* 83.95	.4272* 74.28	.4503 70.46	.5090 62.35	.5365 59.15	.6064* 52.33	.6392* 49.65	.7615* 41.67

HT-65: Wrought, Stress relieved, 1000°C, 1 hr.

S_u = 127-141 ksi
S_y = 125-130 ksi

10 W -- TANTALUM

Composition: See Page 172
(*) Extrapolated Values

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
									PLATE BENDING (Completely Reversed) Effect of Grain Direction								
799	Cold Rolled	Shaped and Ground Edges		80	1.0	Longi. Bending	Weibull	b θ X_o		1.807* 125.3 119.9	1.280 103.7 100.0	1.820 95.73 91.59	1.819* 79.30 75.87	1.500* 73.07 70.28	1.820* 60.56 57.94	1.206* 55.78 53.86	1.778* 42.65 40.83
800	Cold Rolled	Shaped and Ground Edges		80	1.0	Transv. Bending	Normal	σ μ		6.265* 113.8	5.413 98.39	5.083 92.39	4.392 79.83	4.124 74.96	3.563 64.77	3.346* 60.82	2.715* 49.35

S_u = 195 ksi

PURE TUNGSTEN

Composition: See Page 172
(*) Extrapolated Values

TRANSVERSE PLATE BENDING (Completely Reversed)
Miscellaneous

+Code No.	Heat Treat	Surf. Fin.	Freq.	Temp °F	K_t	Other	DIST.	Param.	1x10³	1x10⁴	5x10⁴	1x10⁵	5x10⁵	1x10⁶	5x10⁶	1x10⁷	1x10⁸
801		Ground Edges		80	1.0		L.E.V.	β M	.2347* 190.8	.2661* 168.3	.2904 154.2	.3016 148.5	.3292 136.0	.3419 131.0	.3732 120.0	.3875 115.6	.4393* 101.9

PAGES 351, 352

ARE

MISSING

IN

ORIGINAL

DOCUMENT

A-2.1 A METHOD FOR INTERPOLATING INTERFERENCE VALUES

The values of Interference given in Appendix 2 are highly non-linear. As a result, when interpolation is required to obtain an interference value, a higher order interpolating procedure will be more accurate than a linear one.

One method for interpolating at a higher order is to construct what is called an "interpolating polynomial." The interpolating polynomial gives an n^{th} order interpolation using n + 1 interference values from the table.

A-2.1.1 Higher Order Interpolation Procedure

There are several types of interpolating polynomials, one of the easiest to use is constructed using Neville's Algorithm.[16] This method and the symbols used are:

X	is the value of an interference parameter which does not appear in the interference tables.
$X_o, X_1, \ldots, X_n$	are any n+1 consecutive values of the interference parameters which do appear in the interference tables.
$d=0,1,\ldots,n$	are the consecutive indices.
$P_{k,0}(X)$	$K=0,1,\ldots,n$ are the n+1 interference values corresponding to the values of the interference parameter $X_o, X_1, \ldots, X_n$.
$P_{n,n}(X)$	is the desired n^{th} order interpolated interference value for the interference parameter, X.

$P_{n,n}(X)$ is the last entry of the triangular array of polynomials $P_{k,d}(X)$, (as shown in Table A-2.1 where $P_{k,d}(X)$ is defined as:

$$P_{k,d+1}(X) = \frac{(X_k-X)\, P_{k-1,d}(X) - (X_{k-d-1}-X)P_{k,d}(X)}{X_k - X_{k-d-1}}$$

where $d = 0, 1, \ldots, n$

$k = d+1, d+2, \ldots, n$,

It is important to note that the value of the interference parameter, X, for which the interference must be interpolated can lie anywhere in the interval $X_o \leq X \leq X_n$. However, the value of X may also lie outside this interval, in which case the problem becomes one of extrapolation rather than interpolation.

When the interpolation is required for only one interference parameter, say X, it is called one-way interpolation; and when the interpolation is done for, say two or three parameters, X and Y or X,Y, and Z, it is called two-way and three-way interpolation respectivaly.

	X_k \ d	Interference Values From Table 0	1	2 . . . . . n		
	X_o	$P_{0,0}$				
Values of the Interference Parameter	X_1	$P_{1,0}$	$P_{1,1}(X)$			
	X_2	$P_{2,0}$	$P_{2,1}(X)$	$P_{2,2}(X)$		
	$\vdots$	$\vdots$	$\vdots$	$\vdots$		
	X_n	$P_{n,0}$	$P_{n,1}(X)$	$P_{n,2}(X) \cdots$	$P_{n,n}(X)$	n^{th} order interpolated value of interference at X

Table A-2.1 Construction of the Triangular Array of Polynomials for n^{th} Order

	Interference Parameter	Interference Values From Table			Interference When α=.025 and γ=-2.5
	$-\gamma=X_k$	(d=0) $P_{k,0}$	(d=1) $P_{k,1}$	(d=2) $P_{k,2}$	(d=3) $P_{k,3}$
	X_o=1.0	$P_{0,0}$=.3079			
	X_1=2.0	$P_{1,0}$=.1266	$P_{1,1}$=.0359		
(X=2.5)	X_2=3.0	$P_{2,0}$=.0486	$P_{2,1}$=.0876	$P_{2,2}$=.0747	
	X_3=4.0	$P_{3,0}$=.0182	$P_{3,1}$=.0638	$P_{3,2}$=.0817	$P_{3,3}$=.0782

Table A-2.2 Polynomials for Third Order Interpolation

The following examples will illustrate the application of this higher order interpolating method for one, two, and three-way interpolation problems. In the example chosen, linear, third order and fifth order interpolations were used but this method applies equally well to even and odd order interpolations.

A-2.1.2 Example Problem for One-Way Interpolation

A particular part has Smallest Extreme Value distributed strength with parameters (β,M) and is subjected to Normally distributed stresses with parameters (μ,σ). The calculated interference parameters are:

$$\alpha = \beta\sigma = .025$$

$$\gamma = \beta(\mu - M) = -2.50$$

What is the % Interference?

From the tables in Appendix 2 on Page 422, it is noted that $\alpha = .025$ appears in the table but $\gamma = -2.5$ does not; therefore, the value of interference must be interpolated. The values of interference as read from the above tables are:

$-\gamma$	Interference When $\alpha = .025$
2.0	.1266
3.0	.0486

Linear Interpolation:

If the quick and easy linear interpolation is used, the interference corresponding to $\alpha = .025$ and $\gamma = -2.5$ is found as:

$$\text{Interference} = .1266 + \frac{(.1266-.0486)}{(2.0-3.0)}(3.0-2.5)$$

$$= .1266 - .0390$$

$$= .0876$$

or Percent Interference = 8.76%

Third Order Interpolation:

Using a third order interpolation, by constructing the appropriate polynomials, $P_{k,d}(X)$, the value of $P_{3,3}(X)$ is the interpolated value of interference. Where $P_{3,3}(X)$ is calculated as follows and the results are tabulated in Table A-2.2:

$$P_{k,d+1}(X) = \frac{(X_k - X)P_{k-1,d}(X) - (X_{k-d-1} - X)P_{k,d}(X)}{X_k - X_{k-d-1}}$$

$$P_{1,1}(2.5) = \frac{(2-2.5)(.3079) - (1-2.5)(.1266)}{2 - 1} = .0359$$

$$P_{2,1}(2.5) = \frac{(3-2.5)(.1266) - (2-2.5)(.0486)}{3 - 2} = .0876$$

$$P_{3,1}(2.5) = \frac{(4-2.5)(.0486) - (3-2.5)(.0182)}{4 - 3} = .0638$$

$$P_{2,2}(2.5) = \frac{(3-2.5)(.0359) - (1-2.5)(.0876)}{3 - 1} = .0747$$

$$P_{3,2}(2.5) = \frac{(4-2.5)(.0876) - (2-2.5)(.0638)}{4 - 2} = .0817$$

$$\text{Interference} = P_{3,3}(2.5) = \frac{(4-2.5)(.0747) - (1-2.5)(.0817)}{4 - 1} = .0782$$

or Percent Interference = 7.82%

Thus, it can be seen that the third order interpolation gives significantly more accurate results than the linear interpolation.

Fifth Order Interpolation:

Using a fifth order interpolation, by constructing the appropriate polynomials ($P_{k,d}(X)$), the value of $P_{5,5}(X)$ is the interpolated value of interference where $P_{5,5}(X)$ is calculated as follows and the results are tabulated in Table A-2.3.

$$P_{1,1}(2.5) = \frac{(1-2.5)(.6321) - (0-2.5)(.3079)}{1 - 0} = -.17840$$

$$P_{2,1}(2.5) = \frac{(2-2.5)(.3079) - (1-2.5)(.1266)}{2 - 1} = 0.03595$$

$$P_{3,1}(2.5) = \frac{(3-2.5)(.1266) - (2-2.5)(.0486)}{3 - 2} = 0.08760$$

$$P_{4,1}(2.5) = \frac{(4-2.5)(.0486) - (3-2.5)(.0182)}{4 - 3} = 0.06380$$

$$P_{5,1}(2.5) = \frac{(5-2.5)(.0182) - (4-2.5)(.0067)}{5 - 4} = 0.03545$$

$$P_{2,2}(2.5) = \frac{(2-2.5)(-.17840) - (0-2.5)(.03595)}{2 - 0} = .0895375$$

$$P_{3,2}(2.5) = \frac{(3-2.5)(.03595) - (1-2.5)(.08760)}{3 - 1} = .0746875$$

$$P_{4,2}(2.5) = \frac{(4-2.5)(.08760) - (2-2.5)(.06380)}{4 - 2} = .0816500$$

$$P_{5,2}(2.5) = \frac{(5-2.5)(.06380) - (3-2.5)(.03545)}{5 - 3} = .0708875$$

$\alpha = .025$								
	Interference Parameter	Interference Values From Table						Interference When $\alpha = .025$ and $\gamma = -2.5$
	$-\gamma = X_k$	(d=0) $P_{k,0}$	(d=1) $P_{k,1}$	(d=2) $P_{k,2}$	(d=3) $P_{k,3}$	(d=4) $P_{k,4}$		(d=5) $P_{k,5}$
	$X_o = 0$	$P_{0,0}=.6321$						
	$X_1 = 1.0$	$P_{1,0}=.3079$	$P_{1,1}=-.17840$					
	$X_2 = 2.0$	$P_{2,0}=.1266$	$P_{2,1}=.03595$	$P_{2,2}=.0895375$				
(X=2.5)	$X_3 = 3.0$	$P_{3,0}=.0486$	$P_{3,1}=.08760$	$P_{3,2}=.0746875$	$P_{3,3}=.0771625$			
	$X_4 = 4.0$	$P_{4,0}=.0182$	$P_{4,1}=.06380$	$P_{4,2}=.0816500$	$P_{4,3}=.07816875$	$P_{4,4}=.0777914$		
	$X_5 = 5.0$	$P_{5,0}=.0067$	$P_{5,1}=.03545$	$P_{5,2}=.0708875$	$P_{5,3}=.07985625$	$P_{5,4}=.07880156$		$P_{5,5}=.0783$

Table A-2.3 Polynomials for Fifth Order Interpolation

$$P_{3,3}(2.5) = \frac{(3-2.5)(.0895375) - (0-2.5)(.0746875)}{3-0} = .0771625$$

$$P_{4,3}(2.5) = \frac{(4-2.5)(.0746875) - (1-2.5)(.0816500)}{4-1} = .07816875$$

$$P_{5,3}(2.5) = \frac{(5-2.5)(.0816500) - (2-2.5)(.0708875)}{5-2} = .07985625$$

$$P_{4,4}(2.5) = \frac{(4-2.5)(.0771625) - (0-2.5)(.07816875)}{4-0} = .0777914$$

$$P_{5,4}(2.5) = \frac{(5-2.5)(.07816875) - (1-2.5)(.07985625)}{5-1} = .07880156$$

$$\text{Interference} = P_{5,5}(2.5) = \frac{(5-2.5)(.0777914) - (0-2.5)(.07880156)}{5-0} = .0783$$

or Percent Interference = 7.83%

Thus, the fifth order interpolation does not significantly improve on the third order result for this example.

A-2.1.3 Example Problem for Two-Way and Three-Way Interpolation

Two-Way Interpolation:

The preceeding example demonstrates one-way higher order interpolation The method can be easily extended to the problem of two-way and three-way interpolation where values of 2 or 3 different interference parameters are not in the tables. [For example, α and γ or C,A, and B(x).]

For two-way interpolation of order n, the value of interference corresponding to interference parameters $X = X^*$ and $Y = Y^*$ (as shown in Table A-2.4) is determined as follows:

(1) Determine the interference values $I_0^*, I_1^*, \ldots, I_n^*$ for $X = X_0, \ldots X_n$, at $Y = Y^*$ by performing the n+1 one-way interpolations as discussed in Section A-2.1.2.

(2) Determine the value of interference, I^*, at $X = X^*$, $Y = Y^*$ by performing the one-way interpolation on the interference values $I_0^*, I_1^*, \ldots, I_n^*$ obtained in (1).

The next section on three-way interpolation contains several examples of two-way interpolation.

Three-Way Interpolation:

The need for a three-way interpolation may arise when the fatigue strength is Weibull distributed and the stress is Normal distributed. If the

Y - Interference Parameter

X - Interference Parameter

$X_i \backslash Y_j$	Y_0	Y_1	$(Y^*)\downarrow$	Y_2	$Y_3 \cdots\cdots$	Y_n
X_o	$I_{0,0}$	$I_{0,1}$	$I_0{}^*$	$I_{0,2}$	$I_{0,3} \cdots$	$I_{0,n}$
X_1	$I_{1,0}$	$I_1{}^*$				$\vdots$
$(X^*)\rightarrow \cdots$	$\cdots$	(I^*)				$\vdots$
X_2	$I_{2,0}$	$I_2{}^*$				$\vdots$
X_3	$\vdots$	$\vdots$				$\vdots$
$\vdots$	$\vdots$	$\vdots$				$\vdots$
X_n	$I_{n,0}$	$I_n{}^* \cdots$	$\cdots$	$\cdots$	$\cdots$	$I_{n,n}$

I_{ij} = Interference Value for $X = X_i$ and $Y = Y_j$

Table A-2.4 Interference Table Illustrating a Two-Way Interpolation

interference parameters have values, say $B(x) = b^*$, $A = A^*$ and $C = C^*$, and none of these values are available in the tables, then a three-way interpolation is required to obtain the interference value.

(1) Determine the interference value I_0^{**} for $A = A^*$, $C = C^*$, and for a given value of $B(x) = b_0$ appearing in the tables by performing a two-way interpolation as discussed above. By repeating this for various values of $B(x) = b_0, b_1, b_2, \ldots b_n$, appearing in the tables, n+1 interference values I_0^{**} $I_1^{**}, \ldots, I_n$, will be generated as shown in Table A-2.5 (a) and (b).

(2) Determine the value of interference I^{**} at $B(x) = b^*$, $C = C^*$, $A = A^*$ by performing the one-way interpolation on the interference values $I_0^{**}, I_1^{**}, \ldots, I_n^{**}$ obtained in (1) as shown in Table A-2.6.

As an example of three-way interpolation, consider the Example Problem No. 1, given in Section 9, page 140, where the interference parameters are b = 1.808, C = 3.72, A = .0875. None of these values appear exactly in the tables, so a three-way interpolation is required.

As it involves a great number of calculations for high order three-way interpolations, a second order interpolation will be performed to demonstrate the technique.

For the three-way second order interpolation the following interference values were selected from the Tables in Appendix 2, pages 388 through 392.

The first step is to perform a total of three "two-way" interpolations where each two-way interpolation requires four "one-way" interpolations. The necessary calculations are as follows.

(1) Two-way interpolation within Table A-2.7(a) for b = 1.0, A=.0875, C=3.72

(i) One-way interpolation for A = -.2, b = 1.0, C = 3.72

	$X_k = C_k$	(interference values from tables) $P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	$X_0 = 3.00$	.1372		
	$X_1 = 3.50$	.1210	.113872	
(X = 3.72)	$X_2 = 4.00$	.1081	.115324	.11491744

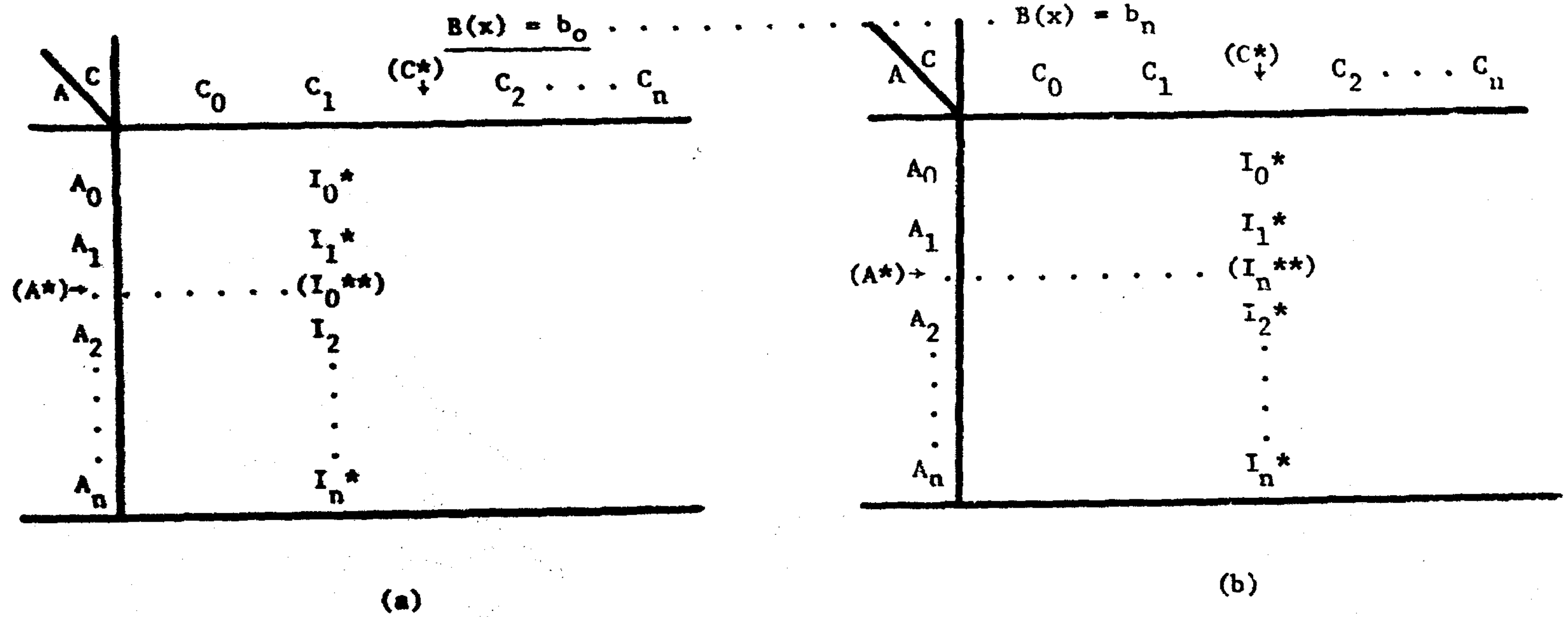


Table A-2.5 Interference Table Illustrating $(n+1)$ Two-Way Interpolations for $(n+1)$ Consecutive Values of $B(x)$

B(x) \ I	Interference Values When A = A* and C = C*
b_0	I_0**
b_1	I_1**
(b*)→	(I**)
b_2	I_2**
.	.
.	.
.	.
.	.
b_n	I_n**

Table A-2.6 Determination of the Interference Value Corresponding to A = A*, C = C*, and B(x) = b* by One-Way Interpolation.

(a)

b	A \ C	3.00	3.50	4.00
	-0.2	.1372	.1210	.1081
b = 1.0	0.0	.1095	.0963	.0860
	0.2	.0852	.0749	.0668

(b)

b	A \ C	3.00	3.50	4.00
	-0.2	.0639	.0490	.0386
b = 2.0	0.0	.0477	.0364	.0286
	0.2	.0348	.0265	.0207

(c)

b	A \ C	3.00	4.00	5.00
	-0.2	.0359	.0166	.0088
b = 3.0	0.0	.0254	.0116	.0062
	0.2	.0176	.0080	.0042

Table A-2.7 Values of Interference as Read from the Tables in Appendix 2

$$P_{k,d+1}(X) = \frac{(X_k - X)\ P_{k-1,d}(X) - (X_{k-d-1}-X)P_{k,d}(X)}{X_k - X_{k-d-1}}$$

$$P_{11}(3.72) = \frac{(3.5 - 3.72)\ (.1372) - (3.0 - 3.72)(.1210)}{3.5 - 3.0} = .113872$$

$$P_{21}(3.72) = \frac{(4.0 - 3.72)(.1210) - (3.5-3.72)(.1081)}{4.0 - 3.5} = .115324$$

$$P_{22}(3.72) = \frac{(4.0-3.72)(.113872) - (3.0 - 3.72)(.115324)}{4.0 - 3.0} = .11491744$$

In a similar manner the following results are obtained!

(ii) One-way interpolation for A = 0, b = 1.0 C = 3.72

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.00	.1095		
	3.50	.0963	.090492	
(3.72)	4.00	.0860	.091688	.09135312

(iii) One-way interpolation for A = .2, b = 1.0, C = 3.72

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.00	.0850		
	3.50	.0749	.070456	
(3.72)	4.00	.0668	.071336	.07108960

(iv) One-way interpolation on the values obtained in (i), (ii), and (iii), to obtain interference for A = .0875, b = 1.0, C = 3.72

	A_k	values obtained in (i), (ii), and (iii) $P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	-0.2	.11491744		
	0.0	.09135312	.08104375	
(.0875)				
	0.2	.07108960	.08248783	.082081676

(2) Two-way interpolation within Table A-2.7; A = .0875, b = 2.0, C = 3.72

(i) One-way interpolation for A = -.2, b = 2.0, C = 3.72

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0639		
	3.5	.0490	.042444	
(3.72)				
	4.0	.0386	.042444	.042444

(ii) One-way interpolation for A = 0, b = 2.0, C = 3.72

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0477		
	3.5	.0364	.031428	
(3.72)				
	4.0	.0286	.032968	.03253680

(iii) One-way interpolation for A = .2, b = 2.0, C = 3.72

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0348		
	3.5	.0265	.022848	
(3.72)				
	4.0	.0207	.023948	.023640

(iv) One-way interpolation on the values obtained in (i), (ii), and (iii), to obtain the interference for $A = .0875$, $b = 2.0$, $C = 3.72$.

	A_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	-0.2	.042444		
	0.0	.0325368	.02820240	
(.0875)				
	0.2	.023640	.02864445	.028520123

(3) Two-way interpolation within Table A-2.7(c) for $A = .0875$, $b = 3.0$, $C = 3.72$.

(i) One-way interpolation for $A = -.2$, $b = 3.0$, $C = 3.72$

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0359		
(3.72)				
	4.0	.0166	.022004	
	5.0	.0088	.018784	.02084480

(ii) One-way interpolation for $A = 0$, $b = 3.0$, $C = 3.72$

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0254		
(3.72)				
	4.0	.0116	.015464	
	5.0	.0062	.013112	.01461728

(iii) One-way interpolation for $A = .2$, $b = 3.0$, $C = 3.72$

	C_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	3.0	.0176		
(3.72				
	4.0	.0080	.010688	
	5.0	.0042	.009064	.01010336

(iv) One-way interpolation on the values obtained (i), (ii), and (iii) to obtain the interference for A = .0875, b = 3.0, C = 3.72.

	A_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
	-0.2	.0208448		
	0.0	.01461728	.01189274	
(.0875)				
	0.2	.01010336	.01264244	.012431587

In the second step, the final result is obtained by performing the one-way interpolation for b = 1.808 on the interference values calculated in part (iv) of (1), (2), and (3) above.

	b_k	$P_{k,0}$	$P_{k,1}$	$P_{k,2}$
(1.808)	1.0	.082081676		
	2.0	.028520123	.038803941	
	3.0	.012431587	.031609122	.035897 = .0359

Thus the interference for b = 1.808, A = .0875, C = 3.72 as obtained by a three-way second order interpolation is:

Interference = .0359 or,

Percent Interference = 3.59%

Interference obtained by the three-way linear interpolation (as shown in Example Problem No. 1 in Section 9, page 141) is:

Percent Interference = 3.98%

Hence, a substantial improvement is provided by using the higher order interpolation.

A-2.2 STRESS DISTRIBUTION - NORMAL
STRENGTH DISTRIBUTION - WEIBULL

A-2.2.1 Stress Standard Deviation = 0

TABLES OF INTERFERENCE [F(X)]

Stress Distribution: Normal

$\mu = S_{equ}$ (Equivalent Stress)

$\sigma = 0$

Strength Distribution: Weibull

X_o, b, θ: Depend on the material and the operating conditions

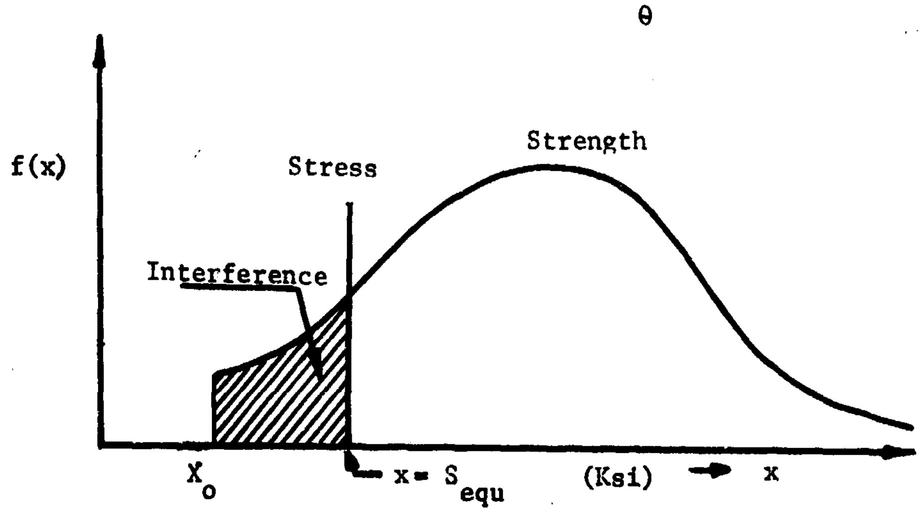


Figure A-2.1 Interference with Standard Deviation of Stress Equal to Zero

Weibull density function is:

$$f(x) = \frac{b}{\theta - X_o}\left(\frac{x - X_o}{\theta - X_o}\right)^{b-1} e^{-\left(\frac{x-X_o}{\theta-X_o}\right)^{b}}$$

Cumulative distribution function, $F(x) = \int_{X_o}^{\infty} f(x)\,dx$

$$\text{Let } y = \left(\frac{x - X_o}{\theta - X_o}\right)^{b}, \quad \therefore \quad dy = \frac{b}{\theta - X_o}\left(\frac{x - X_o}{\theta - X_o}\right)^{b-1} dx$$

$$F(x) = \int_{X_o}^{\infty} f(x)dx = \int_{0}^{\left(\frac{x - X_o}{\theta - X_o}\right)^{b}} e^{-y}\,dy = -e^{-y}\Big|_{0}^{\left(\frac{x - X_o}{\theta - X_o}\right)^{b}} = 1 - e^{-X}$$

$$\text{where } X = \left(\frac{x - X_o}{\theta - X_o}\right)^{b} = \left|\frac{S_{equ} - X_o}{\theta - X_o}\right|^{b}$$

INTERFERENCE, F(X)

X	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.00	0	.001	.002	.003	.00399	.00498	.00598	.00697	.00796	.00896
0.01	.00995	.0109	.0119	.0129	.0139	.0149	.0158	.0168	.0178	.0188
0.02	.0198	.0208	.0217	.0227	.0237	.0246	.0256	.0266	.0276	.0286
0.03	.0295	.0304	.0314	.0324	.0334	.0344	.0353	.0363	.0372	.0382
0.04	.0392	.0401	.0411	.0420	.0430	.0440	.0449	.0458	.0468	.0477
0.05	.0487	.0496	.0506	.0515	.0525	.0535	.0544	.0553	.0562	.0572
0.06	.0581	.0591	.0600	.0610	.0619	.0628	.0637	.0646	.0656	.0665
0.07	.0675	.0685	.0694	.0703	.0712	.0721	.0730	.0740	.0749	.0759
0.08	.0768	.0776	.0786	.0795	.0805	.0814	.0823	.0832	.0841	.0850
0.09	.0860	.0869	.0878	.0887	.0896	.0905	.0914	.0923	.0932	.0941

X	. 0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	.0952	.1042	.1131	.1219	.1306	.1393	.1479	.1563	.1647	.1730
0.2	.1813	.1894	.1975	.2055	.2134	.2212	.2289	.2366	.2442	.2517
0.3	.2592	.2666	.2739	.2811	.2882	.2953	.3023	.3093	.3161	.3229
0.4	.3297	.3363	.3430	.3494	.3560	.3624	.3687	.3750	.3812	.3874
0.5	.3935	.3995	.4055	.4114	.4173	.4231	.4288	.4345	.4401	.4457
0.6	.4512	.4566	.4621	.4674	.4727	.4780	.4831	.4883	.4934	.4984
0.7	.5036	.5084	.5132	.5181	.5229	.5276	.5323	.5370	.5416	.5462
0.8	.5507	.5551	.5596	.5640	.5683	.5726	.5768	.5810	.5852	.5893
0.9	.5934	.5975	.6015	.6054	.6094	.6133	.6171	.6209	.6247	.6284

STRESS DISTRIBUTION – NORMAL (σ=0)

STRENGTH DISTRIBUTION – WEIBULL

X	0	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	0.05	.15	0.25	0.35	0.45	0.55	0.65	0.75	0.85	0.95
1.0	.6321	.6671	.6988	.7275	.7534	.7769	.7981	.8173	.8347	.8504
	.6501	.6834	.7135	.7408	.7654	.7878	.8080	.8262	.8428	.8577
2.0	.8647	.8775	.8892	.8997	.9093	.9179	.9257	.9328	.9392	.9450
	.8713	.8835	.8946	.9046	.9137	.9219	.9293	.9361	.9422	.9477
3.0	.9502	.9550	.9592	.9631	.9666	.9698	.9727	.9753	.9776	.9798
4.0	.9817	.9834	.9850	.9864	.9877	.9889	.9899	.9909	.9918	.9926
5.0	.99326	.99391	.99448	.99501	.99549	.99592	.99630	.99665	.99697	.99726
6.0	.99752	.99776	.99797	.99816	.99836	.99850	.99864	.99877	.99889	.99899
7.0	.999088	.999175	.999253	.999324	.999389	.999447	.999499	.999547	.999590	.999629
8.0	.999665	.999696	.999725	.999751	.999775	.999796	.999816	.999833	.999849	.999864
9.0	.999877	.999888	.999899	.999909	.999917	.999925	.999932	.999939	.999944	.999950
10.0	.999955									

F(X)

STRESS DISTRIBUTION - NORMAL (σ=0)

STRENGTH DISTRIBUGION - WEIBULL

A-2.2.2 Stress Standard Deviation $\neq 0$

TABLES OF INTERFERENCE

Stress Distribution: Normal

$\mu = S_{equ}$ (Equivalent Stress)

$\sigma \neq 0$

Strength Distribution: Weibull

X_o, b or B(x), θ: Depend on the material and the operating conditions

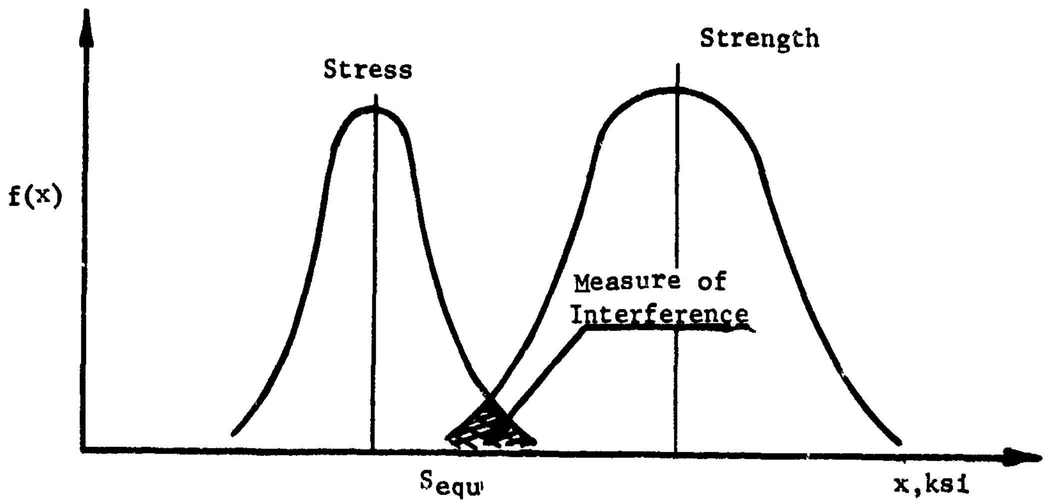


Figure A-22 Interference with Standard Deviation of Stress Not Equal to Zero

B(X) = 1.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
1.0	.0567	.0424	.0338	.0281	.0241	.0210	.0187	.0168	.0153
1.2	.0390	.0290	.0231	.0191	.0164	.0143	.0127	.0114	.0103
1.4	.0259	.0192	.0152	.0126	.0108	.0094	.0083	.0075	.0068
1.6	.0167	.0123	.0097	.0081	.0069	.0060	.0053	.0048	.0043
1.8	.0104	.0077	.0060	.0050	.0042	.0037	.0033	.0029	.0027
2.0	.0063	.0046	.0036	.0030	.0025	.0022	.0020	.0018	.0016
2.2	.0037	.0027	.0021	.0017	.0015	.0013	.0011	.0010	.0009
2.4	.0021	.0015	.0012	.0010	.0008	.0007	.0006	.0006	.0005
2.6	.0011	.0008	.0006	.0005	.0004	.0004	.0003	.0003	.0003
2.8	.0006	.0004	.0003	.0003	.0002	.0002	.0002	.0002	.0001

B(X) = 1.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
1.0	.0140	.0129	.0120	.0112	.0105	.0099	.0093	.0088	.0084
1.2	.0095	.0087	.0081	.0076	.0071	.0067	.0063	.0060	.0057
1.4	.0062	.0057	.0053	.0050	.0046	.0044	.0041	.0039	.0037
1.6	.0040	.0036	.0034	.0031	.0029	.0028	.0026	.0025	.0024
1.8	.0024	.0022	.0021	.0019	.0018	.0017	.0016	.0015	.0014
2.0	.0015	.0013	.0012	.0012	.0011	.0010	.0010	.0009	.0009
2.2	.0008	.0008	.0007	.0007	.0006	.0006	.0006	.0005	.0005
2.4	.0005	.0004	.0004	.0004	.0003	.0003	.0003	.0003	.0003
2.6	.0003	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0001
2.8	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

$B(X) = 1.10$ $\qquad C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0545	.0309	.0212	.0160	.0128	.0106	.0090	.0078	.0069
1.2	.0373	.0209	.0143	.0108	.0086	.0071	.0061	.0053	.0047
1.4	.0247	.0137	.0093	.0070	.0056	.0046	.0039	.0034	.0030
1.6	.0159	.0087	.0059	.0044	.0035	.0029	.0025	.0022	.0019
1.8	.0099	.0054	.0036	.0027	.0022	.0018	.0015	.0013	.0012
2.0	.0059	.0032	.0022	.0016	.0013	.0011	.0009	.0008	.0007
2.2	.0034	.0019	.0012	.0009	.0007	.0006	.0005	.0005	.0004
2.4	.0019	.0010	.0007	.0005	.0004	.0003	.0003	.0002	.0002
2.6	.0010	.0006	.0004	.0003	.0002	.0002	.0002	.0001	.0001
2.8	.0005	.0003	.0002	.0001	.0001	.0001	.0001	.0001	.0001

$B(X) = 1.20$ $\qquad C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0525	.0283	.0187	.0137	.0107	.0087	.0073	.0063	.0055
1.2	.0358	.0190	.0125	.0092	.0071	.0058	.0049	.0042	.0036
1.4	.0236	.0124	.0081	.0059	.0046	.0038	.0032	.0027	.0024
1.6	.0151	.0079	.0051	.0037	.0029	.0024	.0020	.0017	.0015
1.8	.0093	.0048	.0031	.0023	.0018	.0014	.0012	.0010	.0009
2.0	.0056	.0029	.0019	.0013	.0010	.0008	.0007	.0006	.0005
2.2	.0032	.0016	.0011	.0008	.0006	.0005	.0004	.0003	.0003
2.4	.0018	.0009	.0006	.0004	.0003	.0003	.0002	.0002	.0002
2.6	.0010	.0005	.0003	.0002	.0002	.0001	.0001	.0001	.0001
2.8	.0005	.0003	.0002	.0001	.0001	.0001	.0001	.0001	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 1.30

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0507	.0259	.0165	.0118	.0090	.0072	.0059	.0050	.0043
1.2	.0344	.0174	.0110	.0076	.0060	.0048	.0039	.0033	.0029
1.4	.0226	.0113	.0071	.0050	.0038	.0031	.0025	.0021	.0018
1.6	.0144	.0071	.0045	.0032	.0024	.0019	.0016	.0013	.0012
1.8	.0089	.0043	.0027	.0019	.0015	.0012	.0010	.0008	.0007
2.0	.0053	.0026	.0016	.0011	.0009	.0007	.0006	.0005	.0004
2.2	.0030	.0015	.0009	.0006	.0005	.0004	.0003	.0003	.0002
2.4	.0017	.0008	.0005	.0004	.0003	.0002	.0002	.0001	.0001
2.6	.0009	.0004	.0003	.0002	.0001	.0001	.0001	.0001	.0001
2.8	.0005	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000

B(X) = 1.40

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0491	.0239	.0147	.0102	.0076	.0060	.0048	.0040	.0034
1.2	.0332	.0159	.0097	.0067	.0050	.0039	.0032	.0027	.0023
1.4	.0217	.0103	.0062	.0043	.0032	.0025	.0020	.0017	.0014
1.6	.0138	.0064	.0039	.0027	.0020	.0016	.0013	.0011	.0009
1.8	.0084	.0039	.0023	.0016	.0012	.0009	.0008	.0006	.0005
2.0	.0050	.0023	.0014	.0009	.0007	.0005	.0004	.0004	.0003
2.2	.0029	.0013	.0008	.0005	.0004	.0003	.0002	.0002	.0002
2.4	.0016	.0007	.0004	.0003	.0002	.0002	.0001	.0001	.0001
2.6	.0009	.0004	.0002	.0002	.0001	.0001	.0001	.0001	.0001
2.8	.0004	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 1.50

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0476	.0221	.0131	.0088	.0064	.0049	.0040	.0033	.0027
1.2	.0321	.0146	.0086	.0058	.0042	.0032	.0026	.0021	.0018
1.4	.0209	.0094	.0055	.0037	.0027	.0021	.0016	.0014	.0011
1.6	.0132	.0058	.0034	.0023	.0017	.0013	.0010	.0008	.0007
1.8	.0081	.0035	.0020	.0014	.0010	.0008	.0006	.0005	.0004
2.0	.0048	.0021	.0012	.0008	.0006	.0004	.0004	.0003	.0002
2.2	.0027	.0012	.0007	.0004	.0003	.0002	.0002	.0002	.0001
2.4	.0015	.0006	.0004	.0002	.0002	.0001	.0001	.0001	.0001
2.6	.0008	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000
2.8	.0004	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000

B(X) = 1.60

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0463	.0205	.0117	.0076	.0055	.0041	.0032	.0026	.0022
1.2	.0310	.0135	.0076	.0050	.0035	.0027	.0021	.0017	.0014
1.4	.0202	.0096	.0048	.0032	.0022	.0017	.0013	.0011	.0009
1.6	.0127	.0053	.0030	.0019	.0014	.0010	.0008	.0007	.0006
1.8	.0077	.0032	.0018	.0012	.0008	.0006	.0005	.0004	.0003
2.0	.0045	.0019	.0010	.0007	.0005	.0004	.0003	.0002	.0002
2.2	.0026	.0010	.0006	.0004	.0003	.0002	.0002	.0001	.0001
2.4	.0014	.0006	.0003	.0002	.0001	.0001	.0001	.0001	.0001
2.6	.0008	.0003	.0002	.0001	.0001	.0001	.0000	.0000	.0000
2.8	.0004	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 1.70

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0451	.0190	.0104	.0067	.0046	.0034	.0027	.0021	.0018
1.2	.0301	.0125	.0068	.0043	.0030	.0022	.0017	.0014	.0011
1.4	.0195	.0079	.0043	.0027	.0019	.0014	.0011	.0009	.0007
1.6	.0122	.0049	.0026	.0017	.0012	.0009	.0007	.0005	.0004
1.8	.0074	.0029	.0016	.0010	.0007	.0005	.0004	.0003	.0003
2.0	.0044	.0017	.0009	.0006	.0004	.0003	.0002	.0002	.0001
2.2	.0025	.0009	.0005	.0003	.0002	.0002	.0001	.0001	.0001
2.4	.0014	.0005	.0003	.0002	.0001	.0001	.0001	.0001	.0000
2.6	.0007	.0003	.0001	.0001	.0001	.0000	.0000	.0000	.0000
2.8	.0004	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 1.80

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0440	.0177	.0094	.0058	.0040	.0029	.0022	.0017	.0014
1.2	.0293	.0115	.0061	.0037	.0025	.0019	.0014	.0011	.0009
1.4	.0189	.0073	.0038	.0023	.0016	.0012	.0009	.0007	.0006
1.6	.0118	.0045	.0023	.0014	.0010	.0007	.0005	.0004	.0003
1.8	.0071	.0027	.0014	.0008	.0006	.0004	.0003	.0002	.0002
2.0	.0042	.0015	.0008	.0005	.0003	.0002	.0002	.0001	.0001
2.2	.0024	.0009	.0004	.0003	.0002	.0001	.0001	.0001	.0001
2.4	.0013	.0005	.0002	.0001	.0001	.0001	.0001	.0000	.0000
2.6	.0007	.0002	.0001	.0001	.0000	.0000	-.0000	.0000	.0000
2.8	.0003	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

$B(X) = 1.90$

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0430	.0166	.0084	.0051	.0034	.0024	.0018	.0014	.0011
1.2	.0285	.0107	.0054	.0033	.0022	.0015	.0012	.0009	.0007
1.4	.0183	.0067	.0034	.0020	.0013	.0010	.0007	.0006	.0005
1.6	.0114	.0041	.0021	.0012	.0008	.0006	.0004	.0003	.0003
1.8	.0069	.0024	.0012	.0007	.0005	.0003	.0003	.0002	.0002
2.0	.0040	.0014	.0007	.0004	.0003	.0002	.0001	.0001	.0001
2.2	.0023	.0008	.0004	.0002	.0001	.0001	.0001	.0001	.0000
2.4	.0012	.0004	.0002	.0001	.0001	.0001	.0000	.0000	.0000
2.6	.0006	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000
2.8	.0003	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000

$B(X) = 2.00$

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
1.0	.0421	.0244	.0155	.0106	.0076	.0057	.0045	.0036	.0029
1.2	.0278	.0159	.0100	.0068	.0049	.0037	.0028	.0023	.0019
1.4	.0178	.0100	.0063	.0042	.0030	.0023	.0018	.0014	.0011
1.6	.0111	.0061	.0038	.0026	.0018	.0014	.0011	.0008	.0007
1.8	.0066	.0036	.0022	.0015	.0011	.0008	.0006	.0005	.0004
2.0	.0039	.0021	.0013	.0008	.0006	.0005	.0003	.0003	.0002
2.2	.0022	.0012	.0007	.0005	.0003	.0002	.0002	.0002	.0001
2.4	.0012	.0006	.0004	.0002	.0002	.0001	.0001	.0001	.0001
2.6	.0006	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000
2.8	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
1.0	.0024	.0020	.0017	.0015	.0013	.0012	.0010	.0009	.0008
1.2	.0015	.0013	.0011	.0010	.0008	.0007	.0007	.0006	.0005
1.4	.0010	.0008	.0007	.0006	.0005	.0005	.0004	.0004	.0003
1.6	.0006	.0005	.0004	.0004	.0003	.0003	.0002	.0002	.0002
1.8	.0003	.0003	.0002	.0002	.0002	.0002	.0001	.0001	.0001
2.0	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001
2.2	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000
2.4	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 2.10

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0412	.0146	.0065	.0039	.0025	.0017	.0013	.0010	.0007
1.2	.0272	.0093	.0044	.0025	.0016	.0011	.0008	.0006	.0005
1.4	.0174	.0058	.0027	.0015	.0010	.0007	.0005	.0004	.0003
1.6	.0107	.0035	.0016	.0009	.0006	.0004	.0003	.0002	.0002
1.8	.0064	.0021	.0009	.0005	.0003	.0002	.0002	.0001	.0001
2.0	.0037	.0012	.0005	.0003	.0002	.0001	.0001	.0001	.0001
2.2	.0021	.0006	.0003	.0002	.0001	.0001	.0001	.0000	.0000
2.4	.0011	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000
2.6	.0005	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.20

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0404	.0137	.0063	.0035	.0022	.0015	.0010	.0008	.0006
1.2	.0266	.0087	.0040	.0022	.0014	.0009	.0007	.0005	.0004
1.4	.0169	.0054	.0024	.0013	.0008	.0006	.0004	.0003	.0002
1.6	.0105	.0033	.0015	.0008	.0005	.0003	.0002	.0002	.0001
1.8	.0062	.0019	.0008	.0005	.0003	.0002	.0001	.0001	.0001
2.0	.0036	.0011	.0005	.0003	.0002	.0001	.0001	.0001	.0000
2.2	.0020	.0006	.0003	.0001	.0001	.0001	.0000	.0000	.0000
2.4	.0011	.0003	.0001	.0001	.0000	.0000	.0000	.0000	.0000
2.6	.0006	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 2.30

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0397	.0129	.0057	.0031	.0019	.0012	.0009	.0006	.0005
1.2	.0260	.0082	.0036	.0019	.0012	.0008	.0005	.0004	.0003
1.4	.0165	.0051	.0022	.0012	.0007	.0005	.0003	.0002	.0002
1.6	.0102	.0030	.0013	.0007	.0004	.0003	.0002	.0001	.0001
1.8	.0061	.0018	.0007	.0004	.0002	.0002	.0001	.0001	.0001
2.0	.0035	.0010	.0004	.0002	.0001	.0001	.0001	.0000	.0000
2.2	.0019	.0005	.0002	.0001	.0001	.0000	.0000	.0000	.0000
2.4	.0010	.0003	.0001	.0001	.0000	.0000	.0000	.0000	.0000
2.6	.0005	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.40

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.0C	3.C0	4.CC	5.00	6.CC	7.00	8.C0	9.00
1.0	.C390	.C122	.0C52	.CC27	.0C16	.0C11	.CC07	.0CC5	.0004
1.2	.0255	.C077	.0033	.CC17	.0010	.0CC7	.0005	.0003	.0003
1.4	.C162	.C047	.0C20	.CC1C	.0006	.CCC4	.0003	.0002	.0002
1.6	.CC99	.C028	.0C12	.CCC6	.0CC4	.0CC2	.0002	.0001	.0001
1.8	.CC59	.CC16	.00C7	.CCC3	.0C02	.0CC1	.0001	.0001	.0001
2.0	.CC34	.CCC9	.0CC4	.CCC2	.0001	.0CC1	.0001	.00C0	.0000
2.2	.CC19	.CC05	.00C2	.CCC1	.0C01	.0CCC	.0000	.0000	.0CCC
2.4	.CC10	.CCC3	.0CC1	.CCC1	.0000	.0CCC	.C000	.00CC	.0000
2.6	.0C05	.C001	.0CC1	.CCCC	.0000	.0CCC	.0000	.0000	.0000
2.8	.CC03	.CC01	.0CCC	.CCCC	.0C00	.0CCC	.0000	.000C	.0000

B(X) = 2.50

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.0C	3.C0	4.CC	5.00	6.CC	7.00	8.00	9.00
1.0	.C383	.C116	.0C47	.CC24	.0C14	.CCC9	.0006	.0C04	.00C3
1.2	.0250	.CC73	.0C30	.CC15	.0009	.0CC6	.0004	.0003	.0002
1.4	.C158	.CC44	.0C18	.CCC9	.0CC5	.0CC3	.0002	.0002	.0001
1.6	.CC97	.C026	.001C	.CCC5	.0CC3	.CCC2	.0001	.0001	.0001
1.8	.CC57	.0015	.0CC6	.CCC3	.0002	.0CC1	.0001	.0001	.0000
2.0	.CC33	.CC08	.0CC3	.CCC2	.0001	.0CC1	.00C0	.0CCC	.0000
2.2	.CC18	.CC05	.0CC2	.CCC1	.0C01	.0CCC	.0000	.0C0C	.0000
2.4	.CC10	.CC02	.0CC1	.CCCC	.0000	.0CCC	.0000	.000C	.0CCC
2.6	.CC05	.0C01	.00CC	.CCCC	.0000	.00CC	.0000	.000C	.0000
2.8	.CCC3	.CC01	.00CC	.CCCC	.0000	.0CCC	.0000	.0C0C	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.60

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0378	.0110	.0043	.0021	.0012	.0008	.0005	.0004	.0003
1.2	.0245	.0069	.0027	.0013	.0008	.0005	.0003	.0002	.0002
1.4	.0155	.0042	.0016	.0008	.0005	.0003	.0002	.0001	.0001
1.6	.0095	.0025	.0009	.0005	.0003	.0002	.0001	.0001	.0001
1.8	.0056	.0014	.0005	.0003	.0001	.0001	.0001	.0000	.0000
2.0	.0032	.0008	.0003	.0001	.0001	.0001	.0000	.0000	.0000
2.2	.0018	.0004	.0002	.0001	.0000	.0000	.0000	.0000	.0000
2.4	.0009	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0005	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 2.70

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0372	.0104	.0040	.0019	.0011	.0007	.0004	.0003	.0002
1.2	.0242	.0065	.0025	.0012	.0007	.0004	.0003	.0002	.0001
1.4	.0152	.0039	.0015	.0007	.0004	.0002	.0002	.0001	.0001
1.6	.0093	.0023	.0009	.0004	.0002	.0001	.0001	.0001	.0000
1.8	.0055	.0013	.0005	.0002	.0001	.0001	.0001	.0000	.0000
2.0	.0031	.0007	.0003	.0001	.0001	.0000	.0000	.0000	.0000
2.2	.0017	.0004	.0001	.0001	.0000	.0000	.0000	.0000	.0000
2.4	.0009	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0005	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION – Normal
STRENGTH DISTRIBUTION – Weibull

B(X) = 2.80

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0367	.0099	.0037	.0017	.0009	.0006	.0004	.0003	.0002
1.2	.0238	.0062	.0022	.0010	.0006	.0003	.0002	.0002	.0001
1.4	.0150	.0037	.0013	.0006	.0003	.0002	.0001	.0001	.0001
1.6	.0091	.0022	.0008	.0004	.0002	.0001	.0001	.0001	.0000
1.8	.0053	.0012	.0004	.0002	.0001	.0001	.0000	.0000	.0000
2.0	.0030	.0007	.0002	.0001	.0001	.0000	.0000	.0000	.0000
2.2	.0017	.0004	.0001	.0001	.0000	.0000	.0000	.0000	.0000
2.4	.0009	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0005	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 2.90

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0362	.0095	.0034	.0015	.0008	.0005	.0003	.0002	.0002
1.2	.0234	.0058	.0021	.0009	.0005	.0003	.0002	.0001	.0001
1.4	.0147	.0035	.0012	.0005	.0003	.0002	.0001	.0001	.0001
1.6	.0089	.0020	.0007	.0003	.0002	.0001	.0001	.0000	.0000
1.8	.0052	.0012	.0004	.0002	.0001	.0001	.0000	.0000	.0000
2.0	.0030	.0006	.0002	.0001	.0001	.0000	.0000	.0000	.0000
2.2	.0016	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.4	.0009	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0004	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 3.00

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0357	.0090	.0031	.0014	.0007	.0004	.0003	.0002	.0001
1.2	.0231	.0056	.0019	.0008	.0004	.0003	.0002	.0001	.0001
1.4	.0145	.0033	.0011	.0005	.0003	.0001	.0001	.0001	.0000
1.6	.0088	.0019	.0006	.0003	.0001	.0001	.0001	.0000	.0000
1.8	.0051	.0011	.0004	.0002	.0001	.0000	.0000	.0000	.0000
2.0	.0029	.0006	.0002	.0001	.0000	.0000	.0000	.0000	.0000
2.2	.0016	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.4	.0008	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0004	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

B(X) = 3.10

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
1.0	.0353	.0086	.0029	.0012	.0006	.0004	.0002	.0001	.0001
1.2	.0228	.0053	.0017	.0007	.0004	.0002	.0001	.0001	.0001
1.4	.0142	.0032	.0010	.0004	.0002	.0001	.0001	.0001	.0000
1.6	.0086	.0018	.0006	.0002	.0001	.0001	.0000	.0000	.0000
1.8	.0050	.0010	.0003	.0001	.0001	.0000	.0000	.0000	.0000
2.0	.0028	.0006	.0002	.0001	.0000	.0000	.0000	.0000	.0000
2.2	.0016	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000
2.4	.0008	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.6	.0004	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2.8	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 3.20

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A * C	1.00	2.0C	3.C0	4.CC	5.00	6.CC	7.00	8.C0	9.00
1.0	.C349	.CC83	.0C27	.CC11	.0006	.0CC3	.0002	.CC01	.0001
1.2	.0225	.CC51	.0016	.CC(7	.0003	.0CC2	.0001	.0001	.0001
1.4	.C140	.CC30	.0CC9	.CCC4	.0CC2	.0CC1	.0001	.00C0	.0000
1.6	.CC85	.C017	.0CC5	.CCC2	.0C01	.CCC1	.0000	.0000	.0000
1.8	.CC49	.C010	.0CC3	.CCC1	.0001	.0C0C	.0000	.000C	.0000
2.0	.CC28	.CC05	.0CC2	.CCC1	.0000	.0C0C	.0000	.000C	.0000
2.2	.CC15	.0C03	.00C1	.CCCC	.0000	.0CCC	.0000	.000C	.0000
2.4	.CCC8	.CC01	.0CCC	.CCCC	.0000	.0CCC	.0000	.0000	.0000
2.6	.CC04	.C001	.0CCC	.CCCC	.0000	.0CC0	.0000	.0000	.0000
2.8	.CC02	.CC0C	.0CCC	.CCGC	.0000	.0CCC	.0C00	.0000	.0000

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 1.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
.8	.0800	.0602	.0482	.0402	.0344	.0301	.0268	.0241	.0219
.6	.1096	.0830	.0667	.0558	.0479	.0419	.0373	.0336	.0306
.4	.1459	.1113	.0898	.0753	.0647	.0568	.0506	.0456	.0415
.2	.1890	.1452	.1177	.0989	.0852	.0749	.0668	.0602	.0549
.0	.2384	.1847	.1504	.1267	.1095	.0963	.0860	.0776	.0708
-.2	.2933	.2291	.1875	.1585	.1372	.1210	.1081	.0977	.0892
-.4	.3523	.2777	.2285	.1939	.1682	.1486	.1330	.1203	.1099
-.6	.4140	.3294	.2726	.2321	.2020	.1787	.1602	.1452	.1327
-.8	.4765	.3830	.3188	.2726	.2379	.2109	.1894	.1718	.1572
-1.0	.5381	.4370	.3661	.3143	.2751	.2445	.2199	.1998	.1830
-1.4	.6528	.5419	.4601	.3986	.3512	.3136	.2831	.2580	.2369
-1.8	.7493	.6363	.5480	.4794	.4252	.3817	.3460	.3164	.2913
-2.2	.8244	.7160	.6257	.5529	.4941	.4460	.4061	.3725	.3440
-2.6	.8796	.7805	.6920	.6178	.5562	.5049	.4618	.4252	.3938
-3.0	.9184	.8313	.7474	.6739	.6112	.5581	.5127	.4738	.4402
-3.4	.9451	.8706	.7930	.7220	.6597	.6057	.5590	.5185	.4832
-3.8	.9631	.9009	.8305	.7631	.7021	.6483	.6010	.5595	.5229
-4.2	.9753	.9241	.8612	.7981	.7393	.6863	.6390	.5969	.5596
-4.6	.9834	.9418	.8864	.8280	.7719	.7201	.6733	.6312	.5934
-5.0	.9889	.9554	.9070	.8534	.8003	.7504	.7044	.6626	.6247
-5.5	.9933	.9681	.9276	.8800	.8310	.7836	.7391	.6981	.6604
-6.0	.9959	.9771	.9436	.9017	.8569	.8124	.7698	.7298	.6927
-6.5	.9975	.9836	.9561	.9195	.8789	.8374	.7968	.7582	.7220
-7.0	.9985	.9883	.9658	.9341	.8975	.8590	.8207	.7837	.7484
-8.0	.9994	.9940	.9792	.9558	.9265	.8941	.8604	.8268	.7940
-9.0	.9998	.9969	.9874	.9704	.9474	.9204	.8913	.8613	.8314
-10.0	.9999	.9984	.9924	.9802	.9623	.9402	.9153	.8889	.8619

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 1.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
.8	.0201	.0185	.0172	.0161	.0151	.0142	.0134	.0127	.0120
.6	.0280	.0259	.0240	.0224	.0210	.0198	.0187	.0177	.0168
.4	.0381	.0352	.0327	.0305	.0286	.0269	.0255	.0241	.0229
.2	.0504	.0465	.0433	.0404	.0379	.0357	.0338	.0320	.0304
.0	.0650	.0601	.0559	.0523	.0490	.0462	.0437	.0414	.0394
-.2	.0820	.0758	.0706	.0660	.0620	.0584	.0552	.0524	.0498
-.4	.1011	.0936	.0872	.0815	.0766	.0722	.0683	.0648	.0616
-.6	.1222	.1132	.1055	.0987	.0928	.0875	.0828	.0786	.0748
-.8	.1449	.1344	.1252	.1173	.1103	.1040	.0985	.0935	.0890
-1.0	.1688	.1567	.1462	.1369	.1288	.1216	.1152	.1094	.1041
-1.4	.2190	.2036	.1902	.1784	.1680	.1588	.1505	.1430	.1363
-1.8	.2699	.2514	.2352	.2210	.2083	.1971	.1870	.1779	.1696
-2.2	.3195	.2981	.2794	.2629	.2482	.2351	.2233	.2126	.2028
-2.6	.3666	.3428	.3219	.3034	.2868	.2720	.2586	.2464	.2354
-3.0	.4108	.3851	.3622	.3419	.3237	.3074	.2925	.2791	.2668
-3.4	.4521	.4247	.4003	.3784	.3588	.3411	.3250	.3104	.2970
-3.8	.4905	.4618	.4360	.4130	.3921	.3732	.3561	.3404	.3260
-4.2	.5263	.4965	.4697	.4456	.4237	.4038	.3857	.3690	.3537
-4.6	.5595	.5289	.5014	.4764	.4536	.4329	.4139	.3965	.3804
-5.0	.5904	.5593	.5311	.5054	.4820	.4605	.4408	.4227	.4059
-5.5	.6260	.5946	.5658	.5395	.5154	.4932	.4728	.4539	.4364
-6.0	.6585	.6270	.5980	.5713	.5467	.5239	.5029	.4834	.4653
-6.5	.6882	.6568	.6277	.6008	.5759	.5528	.5313	.5113	.4927
-7.0	.7153	.6842	.6553	.6283	.6032	.5799	.5581	.5377	.5187
-8.0	.7626	.7327	.7045	.6778	.6528	.6292	.6071	.5863	.5668
-9.0	.8021	.7737	.7466	.7207	.6961	.6728	.6507	.6298	.6101
-10.0	.8350	.8085	.7827	.7579	.7340	.7112	.6895	.6688	.6490

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
.8	.0616	.0364	.0234	.0160	.0116	.0087	.0068	.0054	.0045
.6	.0876	.0528	.0343	.0237	.0172	.0130	.0101	.0081	.0066
.4	.1209	.0744	.0488	.0340	.0248	.0188	.0147	.0118	.0096
.2	.1621	.1020	.0678	.0475	.0348	.0265	.0207	.0166	.0136
.0	.2113	.1362	.0918	.0648	.0477	.0364	.0286	.0230	.0189
-.2	.2682	.1772	.1211	.0863	.0639	.0490	.0386	.0311	.0255
-.4	.3318	.2248	.1561	.1124	.0838	.0644	.0509	.0411	.0338
-.6	.4003	.2787	.1968	.1431	.1074	.0830	.0657	.0532	.0439
-.8	.4719	.3377	.2427	.1765	.1350	.1048	.0833	.0676	.0558
-1.0	.5443	.4005	.2933	.2164	.1664	.1299	.1037	.0844	.0698
-1.4	.6818	.5312	.4048	.3094	.2401	.1897	.1527	.1250	.1040
-1.8	.7973	.6569	.5220	.4108	.3252	.2606	.2119	.1748	.1462
-2.2	.8828	.7659	.6349	.5154	.4171	.3356	.2793	.2324	.1955
-2.6	.9387	.8514	.7352	.6163	.5107	.4230	.3523	.2959	.2508
-3.0	.9711	.9124	.8178	.7076	.6009	.5070	.4281	.3634	.3105
-3.4	.9877	.9521	.8811	.7856	.6838	.5880	.5040	.4326	.3729
-3.8	.9953	.9757	.9264	.8488	.7566	.6634	.5773	.5015	.4363
-4.2	.9984	.9885	.9568	.8974	.8180	.7311	.6462	.5682	.4993
-4.6	.9995	.9950	.9760	.9330	.8679	.7900	.7090	.6314	.5605
-5.0	.9999	.9980	.9873	.9580	.9068	.8396	.7649	.6898	.6188
-5.5	1.0000	.9994	.9947	.9778	.9422	.8850	.8244	.7550	.6862
-6.0	1.0000	.9998	.9980	.9889	.9657	.9259	.8724	.8108	.7464
-6.5	1.0000	1.0000	.9993	.9948	.9806	.9522	.9098	.8572	.7988
-7.0	1.0000	1.0000	.9998	.9977	.9895	.9702	.9380	.8945	.8433
-8.0	1.0000	1.0000	1.0000	.9996	.9973	.9856	.9731	.9463	.9101
-9.0	1.0000	1.0000	1.0000	1.0000	.9994	.9968	.9895	.9750	.9521
-10.0	1.0000	1.0000	1.0000	1.0000	.9999	.9992	.9964	.9893	.9763

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 2.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
.8	.0037	.0031	.0027	.0023	.0020	.0018	.0016	.0014	.0013
.6	.0055	.0047	.0040	.0035	.0030	.0027	.0024	.0021	.0019
.4	.0080	.0068	.0058	.0050	.0044	.0039	.0034	.0031	.0028
.2	.0114	.0096	.0082	.0071	.0062	.0055	.0049	.0044	.0039
.0	.0158	.0133	.0114	.0099	.0087	.0076	.0068	.0061	.0054
-.2	.0213	.0181	.0155	.0134	.0118	.0104	.0092	.0082	.0074
-.4	.0283	.0240	.0206	.0178	.0156	.0138	.0122	.0110	.0099
-.6	.0367	.0312	.0268	.0232	.0204	.0180	.0160	.0143	.0129
-.8	.0468	.0398	.0342	.0297	.0260	.0230	.0204	.0183	.0165
-1.0	.0587	.0499	.0429	.0373	.0327	.0289	.0257	.0230	.0207
-1.4	.0877	.0748	.0645	.0562	.0493	.0436	.0389	.0348	.0314
-1.8	.1237	.1059	.0916	.0799	.0703	.0623	.0555	.0498	.0449
-2.2	.1664	.1430	.1240	.1085	.0956	.0848	.0758	.0680	.0614
-2.6	.2146	.1853	.1613	.1415	.1250	.1111	.0994	.0894	.0808
-3.0	.2673	.2319	.2027	.1784	.1580	.1408	.1262	.1136	.1028
-3.4	.3233	.2820	.2475	.2186	.1942	.1735	.1558	.1406	.1274
-3.8	.3811	.3344	.2949	.2615	.2331	.2088	.1879	.1699	.1542
-4.2	.4395	.3881	.3441	.3064	.2741	.2462	.2222	.2013	.1831
-4.6	.4975	.4423	.3943	.3527	.3166	.2854	.2582	.2344	.2136
-5.0	.5539	.4959	.4446	.3996	.3602	.3258	.2956	.2690	.2457
-5.5	.6209	.5609	.5068	.4584	.4154	.3773	.3436	.3138	.2874
-6.0	.6828	.6226	.5669	.5161	.4703	.4293	.3926	.3598	.3305
-6.5	.7387	.6798	.6239	.5719	.5242	.4808	.4416	.4062	.3743
-7.0	.7880	.7319	.6771	.6250	.5763	.5313	.4901	.4526	.4185
-8.0	.8669	.8194	.7659	.7205	.6725	.6266	.5834	.5431	.5058
-9.0	.9214	.8845	.8433	.7998	.7554	.7114	.6685	.6277	.5889
-10.0	.9564	.9300	.8980	.8620	.8235	.7836	.7435	.7039	.6655

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

E(X) = 3.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0535	.0142	.0050	.0022	.0012	.0007	.0004	.0003	.0002
.6	.0777	.0218	.0078	.0035	.0018	.0011	.0007	.0005	.0003
.4	.1093	.0325	.0118	.0053	.0028	.0016	.0010	.0007	.0005
.2	.1495	.0471	.0176	.0080	.0042	.0025	.0016	.0011	.0007
.0	.1960	.0664	.0254	.0116	.0062	.0036	.0023	.0015	.0011
-.2	.2551	.0914	.0359	.0166	.0088	.0052	.0033	.0022	.0016
-.4	.3198	.1226	.0496	.0232	.0124	.0073	.0047	.0031	.0022
-.6	.3906	.1605	.0670	.0318	.0171	.0101	.0064	.0043	.0031
-.8	.4651	.2051	.0886	.0426	.0230	.0137	.0087	.0059	.0042
-1.0	.5408	.2563	.1146	.0561	.0305	.0182	.0116	.0078	.0055
-1.4	.6854	.3750	.1819	.0922	.0510	.0306	.0197	.0133	.0094
-1.8	.8058	.5065	.2681	.1418	.0800	.0486	.0314	.0213	.0151
-2.2	.8930	.6369	.3702	.2057	.1189	.0731	.0475	.0324	.0230
-2.6	.9470	.7528	.4814	.2827	.1683	.1049	.0688	.0472	.0336
-3.0	.9773	.8452	.5936	.3703	.2278	.1446	.0958	.0661	.0473
-3.4	.9914	.9112	.6981	.4643	.2964	.1921	.1287	.0894	.0643
-3.8	.9971	.9536	.7884	.5596	.3721	.2469	.1678	.1175	.0849
-4.2	.9992	.9780	.8604	.6513	.4524	.3082	.2127	.1505	.1093
-4.6	.9998	.9905	.9137	.7346	.5340	.3744	.2630	.1881	.1377
-5.0	1.0000	.9963	.9501	.8064	.6139	.4439	.3180	.2302	.1698
-5.5	1.0000	.9990	.9772	.8775	.7067	.5323	.3917	.2886	.2153
-6.0	1.0000	.9998	.9907	.9286	.7876	.6188	.4687	.3521	.2661
-6.5	1.0000	1.0000	.9960	.9608	.8537	.6994	.5463	.4192	.3214
-7.0	1.0000	1.0000	.9989	.9804	.9045	.7713	.6219	.4882	.3803
-8.0	1.0000	1.0000	.9999	.9962	.9658	.8820	.7575	.6242	.5038
-9.0	1.0000	1.0000	1.0000	.9995	.9904	.9485	.8614	.7458	.6257
-10.0	1.0000	1.0000	1.0000	1.0000	.9979	.9813	.9303	.8430	.7359

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 4.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0491	.0100	.0026	.0009	.0004	.0002	.0001	.0001	.0000
.6	.0722	.0159	.0042	.0014	.0006	.0003	.0002	.0001	.0001
.4	.1028	.0245	.0066	.0023	.0010	.0005	.0003	.0001	.0001
.2	.1418	.0366	.0103	.0036	.0015	.0007	.0004	.0002	.0001
.0	.1899	.0534	.0156	.0055	.0023	.0011	.0006	.0004	.0002
-.2	.2463	.0756	.0230	.0083	.0035	.0017	.0009	.0006	.0003
-.4	.3117	.1043	.0332	.0121	.0052	.0026	.0014	.0008	.0005
-.6	.3832	.1401	.0467	.0174	.0075	.0037	.0020	.0012	.0007
-.8	.4588	.1835	.0644	.0245	.0107	.0053	.0029	.0017	.0011
-1.0	.5360	.2344	.0868	.0338	.0149	.0074	.0040	.0024	.0015
-1.4	.6837	.3562	.1480	.0609	.0275	.0138	.0076	.0045	.0028
-1.8	.8067	.4948	.2328	.1022	.0474	.0241	.0133	.0079	.0050
-2.2	.8950	.6343	.3394	.1605	.0772	.0399	.0222	.0132	.0083
-2.6	.9497	.7581	.4609	.2369	.1189	.0627	.0353	.0211	.0133
-3.0	.9788	.8549	.5865	.3299	.1742	.0941	.0536	.0323	.0205
-3.4	.9922	.9216	.7042	.4351	.2432	.1354	.0784	.0476	.0303
-3.8	.9975	.9620	.8039	.5456	.3248	.1874	.1105	.0679	.0435
-4.2	.9993	.9836	.8803	.6532	.4161	.2500	.1508	.0937	.0605
-4.6	.9998	.9937	.9331	.7502	.5127	.3223	.1995	.1259	.0819
-5.0	1.0000	.9979	.9659	.8311	.6091	.4022	.2565	.1647	.1082
-5.5	1.0000	.9995	.9872	.9059	.7212	.5084	.3383	.2227	.1487
-6.0	1.0000	.9999	.9959	.9532	.8157	.6150	.4289	.2909	.1977
-6.5	1.0000	1.0000	.9989	.9794	.8879	.7145	.5241	.3677	.2554
-7.0	1.0000	1.0000	.9997	.9920	.9377	.8007	.6189	.4507	.3208
-8.0	1.0000	1.0000	1.0000	.9992	.9857	.9209	.7869	.6217	.4688
-9.0	1.0000	1.0000	1.0000	1.0000	.9979	.9769	.9037	.7746	.6237
-10.0	1.0000	1.0000	1.0000	1.0000	.9993	.9953	.9660	.8870	.7637

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 5.00

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0464	.0078	.0015	.0004	.0001	.0001	.0000	.0000	.0000
.6	.0687	.0127	.0025	.0007	.0002	.0001	.0000	.0000	.0000
.4	.0986	.0200	.0042	.0011	.0004	.0002	.0001	.0000	.0000
.2	.1369	.0307	.0068	.0018	.0006	.0003	.0001	.0001	.0000
.0	.1844	.0457	.0106	.0029	.0010	.0004	.0002	.0001	.0001
-.2	.2410	.0662	.0162	.0046	.0016	.0006	.0003	.0002	.0001
-.4	.3060	.0931	.0243	.0070	.0024	.0010	.0005	.0002	.0001
-.6	.3776	.1274	.0354	.0105	.0037	.0015	.0007	.0004	.0002
-.8	.4538	.1697	.0504	.0154	.0055	.0023	.0011	.0005	.0003
-1.0	.5318	.2201	.0701	.0222	.0080	.0033	.0015	.0008	.0004
-1.4	.6813	.3430	.1267	.0432	.0160	.0067	.0032	.0016	.0009
-1.8	.8059	.4856	.2094	.0781	.0301	.0128	.0061	.0031	.0018
-2.2	.8952	.6304	.3179	.1312	.0531	.0231	.0110	.0057	.0032
-2.6	.9502	.7588	.4454	.2054	.0881	.0394	.0190	.0100	.0056
-3.0	.9792	.8583	.5795	.3007	.1383	.0639	.0314	.0165	.0093
-3.4	.9925	.9256	.7056	.4129	.2054	.0989	.0495	.0263	.0149
-3.8	.9976	.9653	.8112	.5338	.2894	.1463	.0751	.0404	.0230
-4.2	.9993	.9857	.8898	.6525	.3878	.2074	.1096	.0599	.0343
-4.6	.9998	.9948	.9419	.7587	.4952	.2822	.1545	.0860	.0497
-5.0	1.0000	.9983	.9724	.8450	.6041	.3688	.2105	.1198	.0702
-5.5	1.0000	.9997	.9907	.9208	.7302	.4883	.2958	.1743	.1040
-6.0	1.0000	.9999	.9974	.9648	.8336	.6109	.3958	.2430	.1485
-6.5	1.0000	1.0000	.9994	.9865	.9080	.7251	.5050	.3253	.2046
-7.0	1.0000	1.0000	.9999	.9956	.9549	.8213	.6157	.4186	.2725
-8.0	1.0000	1.0000	1.0000	.9997	.9927	.9432	.8091	.6191	.4380
-9.0	1.0000	1.0000	1.0000	1.0000	.9993	.9883	.9303	.7974	.6216
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9985	.9823	.9168	.7866

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 6.00

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0446	.0065	.0010	.0002	.0001	.0000	.0000	.0000	.0000
.6	.0664	.0107	.0017	.0003	.0001	.0000	.0000	.0000	.0000
.4	.0957	.0173	.0029	.0006	.0002	.0001	.0000	.0000	.0000
.2	.1335	.0270	.0048	.0010	.0003	.0001	.0000	.0000	.0000
.0	.1806	.0408	.0078	.0017	.0005	.0002	.0001	.0000	.0000
-.2	.2369	.0601	.0123	.0028	.0008	.0003	.0001	.0000	.0000
-.4	.3017	.0857	.0190	.0044	.0012	.0004	.0002	.0001	.0000
-.6	.3734	.1189	.0285	.0069	.0020	.0007	.0003	.0001	.0001
-.8	.4498	.1603	.0417	.0105	.0030	.0010	.0004	.0002	.0001
-1.0	.5282	.2102	.0594	.0156	.0046	.0016	.0006	.0003	.0001
-1.4	.6789	.3334	.1124	.0325	.0100	.0035	.0014	.0006	.0003
-1.8	.8047	.4782	.1930	.0626	.0202	.0073	.0029	.0013	.0007
-2.2	.8948	.6263	.3021	.1113	.0383	.0141	.0058	.0026	.0013
-2.6	.9502	.7579	.4333	.1830	.0680	.0259	.0108	.0049	.0025
-3.0	.9794	.8594	.5731	.2790	.1134	.0451	.0191	.0088	.0044
-3.4	.9926	.9273	.7048	.3956	.1779	.0746	.0324	.0151	.0076
-3.8	.9977	.9668	.8143	.5236	.2626	.1174	.0525	.0248	.0125
-4.2	.9994	.9866	.8946	.6503	.3654	.1758	.0817	.0393	.0200
-4.6	.9999	.9953	.9463	.7630	.4806	.2510	.1222	.0601	.0309
-5.0	1.0000	.9985	.9756	.8528	.5988	.3419	.1757	.0889	.0464
-5.5	1.0000	.9997	.9923	.9290	.7354	.4714	.2620	.1385	.0739
-6.0	1.0000	1.0000	.9980	.9707	.8448	.6066	.3682	.2055	.1130
-6.5	1.0000	1.0000	.9996	.9898	.9199	.7321	.4883	.2904	.1657
-7.0	1.0000	1.0000	.9999	.9970	.9641	.8352	.6121	.3912	.2334
-8.0	1.0000	1.0000	1.0000	.9999	.9954	.9560	.8250	.6162	.4112
-9.0	1.0000	1.0000	1.0000	1.0000	.9997	.9931	.9466	.8147	.6192
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9994	.9897	.9363	.8047

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 7.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0433	.0056	.0007	.0001	.0000	.0000	.0000	.0000	.0000
.6	.0647	.0095	.0012	.0002	.0000	.0000	.0000	.0000	.0000
.4	.0936	.0154	.0021	.0004	.0001	.0000	.0000	.0000	.0000
.2	.1310	.0245	.0037	.0006	.0001	.0000	.0000	.0000	.0000
.0	.1777	.0375	.0061	.0011	.0002	.0001	.0000	.0000	.0000
-.2	.2337	.0558	.0099	.0018	.0004	.0001	.0000	.0000	.0000
-.4	.2983	.0806	.0156	.0030	.0007	.0002	.0001	.0000	.0000
-.6	.3701	.1129	.0240	.0048	.0011	.0003	.0001	.0000	.0000
-.8	.4467	.1535	.0359	.0075	.0018	.0005	.0002	.0001	.0000
-1.0	.5253	.2028	.0522	.0116	.0028	.0008	.0003	.0001	.0000
-1.4	.6768	.3260	.1023	.0257	.0066	.0019	.0007	.0003	.0001
-1.8	.8034	.4722	.1810	.0522	.0143	.0043	.0015	.0006	.0003
-2.2	.8942	.6225	.2901	.0972	.0239	.0090	.0032	.0013	.0006
-2.6	.9500	.7563	.4236	.1665	.0544	.0178	.0064	.0026	.0011
-3.0	.9793	.8594	.5673	.2624	.0958	.0330	.0121	.0049	.0022
-3.4	.9926	.9280	.7030	.3818	.1574	.0581	.0219	.0089	.0040
-3.8	.9977	.9675	.8154	.5149	.2417	.0966	.0378	.0157	.0070
-4.2	.9994	.9871	.8970	.6474	.3474	.1520	.0625	.0265	.0120
-4.6	.9999	.9955	.9487	.7648	.4692	.2266	.0987	.0430	.0197
-5.0	1.0000	.9987	.9774	.8573	.5935	.3200	.1491	.0672	.0313
-5.5	1.0000	.9993	.9932	.9338	.7381	.4569	.2348	.1118	.0534
-6.0	1.0000	1.0000	.9983	.9741	.8518	.6020	.3452	.1760	.0871
-6.5	1.0000	1.0000	.9997	.9915	.9273	.7365	.4738	.2617	.1357
-7.0	1.0000	1.0000	.9999	.9977	.9694	.8446	.6083	.3678	.2018
-8.0	1.0000	1.0000	1.0000	.9999	.9967	.9636	.8364	.6130	.3878
-9.0	1.0000	1.0000	1.0000	1.0000	.9998	.9953	.9567	.8277	.6166
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9997	.9933	.9489	.8188

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 8.00

$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0423	.0050	.0005	.0001	.0000	.0000	.0000	.0000	.0000
.6	.0634	.0086	.0009	.0001	.0000	.0000	.0000	.0000	.0000
.4	.0920	.0142	.0017	.0002	.0000	.0000	.0000	.0000	.0000
.2	.1291	.0227	.0030	.0004	.0001	.0000	.0000	.0000	.0000
.0	.1755	.0351	.0050	.0007	.0001	.0000	.0000	.0000	.0000
-.2	.2313	.0528	.0083	.0013	.0002	.0001	.0000	.0000	.0000
-.4	.2957	.0768	.0134	.0021	.0004	.0001	.0000	.0000	.0000
-.6	.3674	.1084	.0209	.0035	.0007	.0002	.0000	.0000	.0000
-.8	.4441	.1494	.0318	.0057	.0011	.0003	.0001	.0000	.0000
-1.0	.5229	.1972	.0471	.0090	.0018	.0004	.0001	.0000	.0000
-1.4	.6750	.3202	.0949	.0211	.0046	.0011	.0003	.0001	.0000
-1.8	.8023	.4673	.1719	.0448	.0105	.0027	.0008	.0003	.0001
-2.2	.8937	.6192	.2808	.0869	.0226	.0060	.0018	.0006	.0003
-2.6	.9498	.7547	.4157	.1540	.0449	.0127	.0039	.0014	.0005
-3.0	.9793	.8590	.5621	.2494	.0828	.0250	.0079	.0028	.0011
-3.4	.9926	.9282	.7008	.3706	.1418	.0464	.0153	.0055	.0022
-3.8	.9977	.9679	.8156	.5074	.2253	.0812	.0280	.0102	.0041
-4.2	.9994	.9874	.8982	.6442	.3327	.1337	.0489	.0183	.0074
-4.6	.9999	.9957	.9501	.7653	.4577	.2072	.0812	.0314	.0128
-5.0	1.0000	.9987	.9784	.8598	.5884	.3020	.1285	.0518	.0215
-5.5	1.0000	.9998	.9936	.9367	.7392	.4444	.2129	.0917	.0393
-6.0	1.0000	1.0000	.9985	.9761	.8562	.5974	.3259	.1525	.0682
-6.5	1.0000	1.0000	.9997	.9925	.9320	.7390	.4611	.2379	.1125
-7.0	1.0000	1.0000	1.0000	.9981	.9727	.8509	.6043	.3477	.1761
-8.0	1.0000	1.0000	1.0000	.9999	.9974	.9684	.8444	.6096	.3674
-9.0	1.0000	1.0000	1.0000	1.0000	.9999	.9965	.9633	.8372	.6137
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9998	.9952	.9573	.8296

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 9.00

$C = \frac{\theta - x_o}{\sigma}$, $A = \frac{x_o - \mu}{\sigma}$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0416	.0046	.0004	.0000	.0000	.0000	.0000	.0000	.0000
.6	.0624	.0079	.0008	.0001	.0000	.0000	.0000	.0000	.0000
.4	.0907	.0133	.0014	.0001	.0000	.0000	.0000	.0000	.0000
.2	.1276	.0214	.0025	.0003	.0000	.0000	.0000	.0000	.0000
.0	.1737	.0334	.0043	.0005	.0001	.0000	.0000	.0000	.0000
-.2	.2293	.0505	.0072	.0009	.0001	.0000	.0000	.0000	.0000
-.4	.2936	.0739	.0118	.0016	.0002	.0000	.0000	.0000	.0000
-.6	.3653	.1049	.0187	.0027	.0004	.0001	.0000	.0000	.0000
-.8	.4420	.1444	.0289	.0045	.0007	.0002	.0000	.0000	.0000
-1.0	.5209	.1929	.0433	.0073	.0012	.0003	.0001	.0000	.0000
-1.4	.6734	.3155	.0893	.0178	.0033	.0007	.0002	.0001	.0000
-1.8	.8013	.4631	.1649	.0395	.0081	.0018	.0005	.0001	.0000
-2.2	.8931	.6162	.2733	.0792	.0182	.0042	.0011	.0003	.0001
-2.6	.9495	.7530	.4092	.1443	.0380	.0093	.0025	.0008	.0003
-3.0	.9792	.8584	.5575	.2390	.0730	.0195	.0054	.0017	.0006
-3.4	.9925	.9282	.6986	.3613	.1296	.0380	.0110	.0035	.0012
-3.8	.9977	.9680	.8151	.5008	.2121	.0696	.0213	.0068	.0024
-4.2	.9994	.9875	.8988	.6410	.3206	.1194	.0391	.0129	.0046
-4.6	.9999	.9958	.9509	.7650	.4486	.1915	.0681	.0234	.0085
-5.0	1.0000	.9987	.9790	.8612	.5836	.2870	.1125	.0407	.0151
-5.5	1.0000	.9998	.9939	.9385	.7393	.4336	.1949	.0764	.0294
-6.0	1.0000	1.0000	.9986	.9773	.8590	.5929	.3095	.1337	.0542
-6.5	1.0000	1.0000	.9997	.9931	.9351	.7402	.4499	.2181	.0944
-7.0	1.0000	1.0000	1.0000	.9983	.9749	.8552	.6003	.3304	.1552
-8.0	1.0000	1.0000	1.0000	.9999	.9978	.9716	.8501	.6060	.3496
-9.0	1.0000	1.0000	1.0000	1.0000	.9999	.9972	.9676	.8443	.6106
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9999	.9963	.9630	.8379

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

B(X) = 10.00

$$C = \frac{\theta - x_o}{\sigma}, \quad A = \frac{x_o - \mu}{\sigma}$$

A \ C	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
.8	.0410	.0043	.0003	.0000	.0000	.0000	.0000	.0000	.0000
.6	.0616	.0075	.0006	.0001	.0000	.0000	.0000	.0000	.0000
.4	.0897	.0126	.0012	.0001	.0000	.0000	.0000	.0000	.0000
.2	.1263	.0204	.0021	.0002	.0000	.0000	.0000	.0000	.0000
.0	.1723	.0320	.0037	.0004	.0000	.0000	.0000	.0000	.0000
-.2	.2277	.0487	.0064	.0007	.0001	.0000	.0000	.0000	-.0000
-.4	.2919	.0717	.0106	.0013	.0002	.0000	.0000	.0000	-.0000
-.6	.3635	.1022	.0171	.0022	.0003	.0000	.0000	.0000	-.0000
-.8	.4402	.1412	.0267	.0037	.0005	.0001	.0000	.0000	.0000
-1.0	.5192	.1893	.0404	.0061	.0009	.0002	.0000	.0000	.0000
-1.4	.6721	.3117	.0850	.0155	.0025	.0004	.0001	.0000	.0000
-1.8	.8004	.4597	.1593	.0355	.0064	.0012	.0003	.0001	.0000
-2.2	.8926	.6136	.2672	.0732	.0151	.0030	.0007	.0002	.0001
-2.6	.9493	.7515	.4037	.1366	.0329	.0071	.0016	.0004	.0001
-3.0	.9791	.8577	.5535	.2306	.0656	.0155	.0038	.0010	.0003
-3.4	.9925	.9280	.6964	.3535	.1200	.0318	.0081	.0022	.0007
-3.8	.9977	.9680	.8145	.4950	.2014	.0608	.0165	.0047	.0015
-4.2	.9994	.9876	.8990	.6379	.3104	.1081	.0318	.0094	.0030
-4.6	.9999	.9958	.9513	.7642	.4407	.1787	.0580	.0178	.0058
-5.0	1.0000	.9988	.9794	.8619	.5791	.2745	.0997	.0325	.0108
-5.5	1.0000	.9998	.9941	.9397	.7388	.4242	.1801	.0645	.0224
-6.0	1.0000	1.0000	.9987	.9782	.8608	.5886	.2956	.1186	.0436
-6.5	1.0000	1.0000	.9998	.9935	.9372	.7405	.4400	.2015	.0801
-7.0	1.0000	1.0000	1.0000	.9984	.9763	.8581	.5962	.3154	.1379
-8.0	1.0000	1.0000	1.0000	1.0000	.9981	.9738	.8542	.6024	.3339
-9.0	1.0000	1.0000	1.0000	1.0000	.9999	.9976	.9707	.8495	.6074
-10.0	1.0000	1.0000	1.0000	1.0000	1.0000	.9999	.9970	.9670	.8442

STRESS DISTRIBUTION - Normal
STRENGTH DISTRIBUTION - Weibull

A-2.3 STRESS DISTRIBUTION - NORMAL
STRENGTH DISTRIBUTION - NORMAL

A-2.3.1 Stress Standard Deviation = 0

TABLES OF INTERFERENCE

Stress Distribution: Normal

$\mu_y = S_{equ}$ (Equivalent Stress)

$\sigma_y = 0$

Strength Distribution: Normal

μ_x, σ_x Depend on the material and the operating conditions

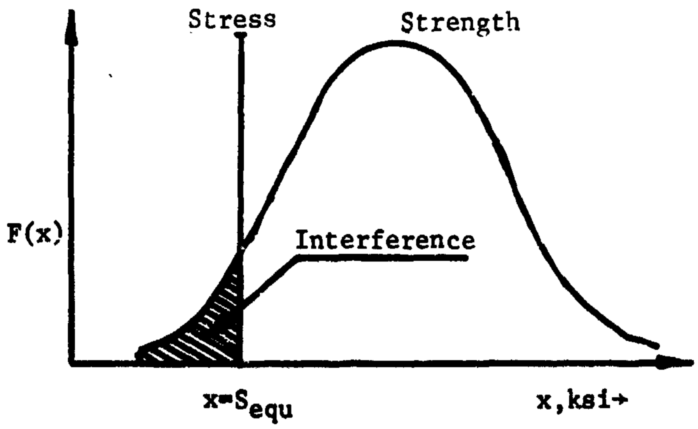


Figure A-2.3 Interference With Standard Deviation of Stress Equal to Zero

The interference is the area under the standardized normal curve corresponding to the value of the standardized normal variate, z, determined from Equation (2.1) in Section 2.

$$z = \frac{|\mu_y - \mu_x|}{\sqrt{\sigma_x^2 + \sigma_y^2}} = \frac{|S_{equ} - \mu_x|}{\sigma_x}$$

The value of interference corresponding to the value of z can be obtained from Table 2.1 (in Section 2) of α vs. K_α where:

α = interference

$K_\alpha = z$

A-2.3.2 Stress Standard Deviation $\neq 0$

TABLE OF INTERFERENCE

Stress Distribution: Normal

$\mu_y = S_{equ}$ (Equivalent Stress)

$\sigma_y \neq 0$

Strength Distribution: Normal

μ_x, σ_x Depend on the material and the operating conditions

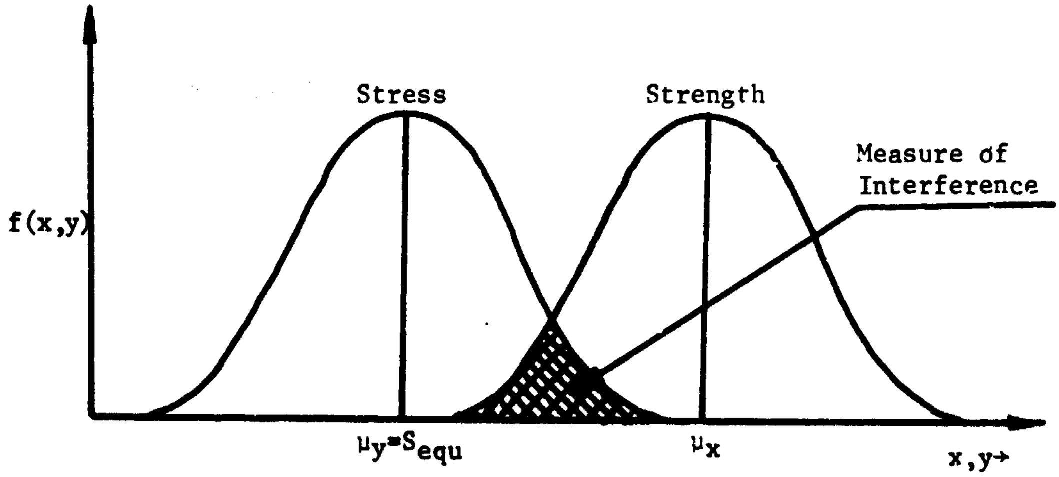


Figure A-2.4 Interference with Standard Deviation of Stress Not Equal to Zero

The interference is the area under the standardized normal curve corresponding to the value of standardized normal variate, z, determined from the Equation (2.1) in Section 2.

$$z = \frac{|\mu_y - \mu_x|}{\sqrt{\sigma_x^2 + \sigma_y^2}}$$

The value of interference corresponding to the value of z can be obtained from Table 2.1 (in Section 2) of α vs. K_α where:

α = interference

$K_\alpha = z$

A-2.4 STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

A-2.4.1 STRESS STANDARD DEVIATION = 0

TABLES OF INTERFERENCE [F(X)]

Stress Distribution: Normal

$\mu = S_{equ}$ (Equivalent Stress)

$\sigma = 0$

Strength Distribution: Largest Extreme Value

M
Depend on the material
and the operating conditions
β

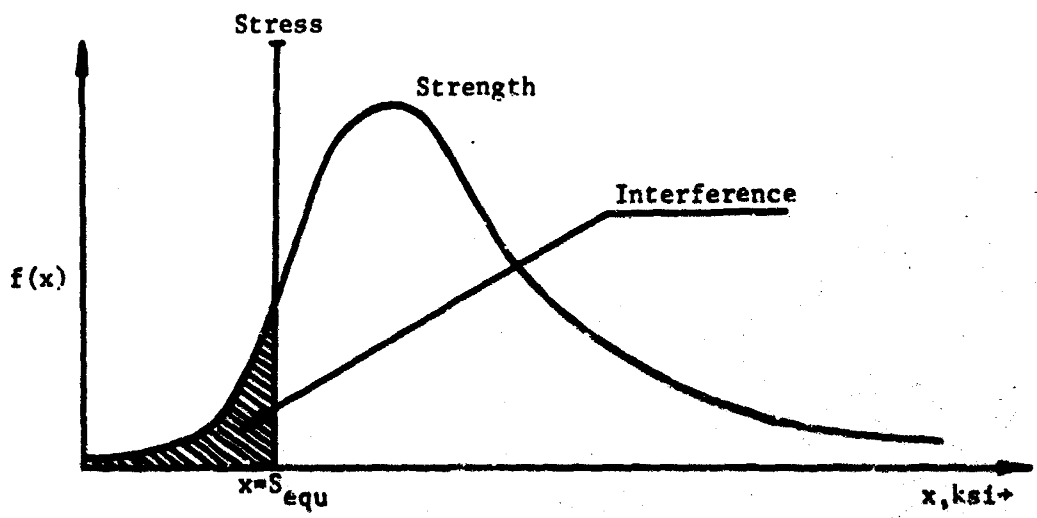


Figure A-2.5 Interference With Standard Deviation of Stress Equal to Zero

Density function of Largest Extreme Value is:

$$f(x) = \beta\, e^{-\beta(x-M)} \cdot e^{-e^{-\beta(x-M)}}$$

Cumulative distribution function, $F(x) = \int_{-\infty}^{+\infty} f(x)\, dx$

Let $y = -e^{-\beta(x-M)} \therefore dy = +\beta\, e^{-\beta(x-M)}\, dx$

$$F(x=S_{equ}) = \int_{-\infty}^{-e^{-\beta(S_{equ}-M)}} e^{+y}\, dy = e^{+y} \Big|_{-\infty}^{-e^{-\beta(S_{equ}-M)}} = e^{-e^{-\beta(S_{equ}-M)}}$$

$F(X) = e^{-e^{+X}}$ where $X = -\beta(S_{equ}-M)$

X	Interference F(X)	X	Interference F(X)
0.00	.3679	1.15	.0425
0.05	.3495	1.20	.0361
0.10	.3312	1.25	.0305
0.15	.3129	1.30	.6255
0.20	.2948	1.35	.0211
0.25	.2769	1.40	.0173
0.30	.2593	1.45	.0141
0.35	.2419	1.50	.0113
0.40	.2249	1.55	.0090
0.45	.2084	1.60	.0071
0.50	.1923	1.65	.0055
0.55	.1767	1.70	.0042
0.60	.1617	1.75	.0032
0.65	.1473	1.80	.0024
0.70	.1335	1.85	.0017
0.75	.1204	1.90	.0012
0.80	.1080	1.95	.0009
0.85	.0964	2.00	.0006
0.90	.0855	2.05	.0004
0.95	.0753	2.10	.0003
1.00	.0660	2.15	.0002
1.05	.0574	2.20	.0001
1.10	.0496	2.25	.0000

Where $X = -\beta(S_{equ} - M)$

STRESS DISTRIBUTION - NORMAL ($\sigma = 0$)

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

A-2.4.2 Stress Standard Deviation $\neq 0$

TABLES OF INTERFERENCE

Stress Distribution: Normal

$\mu = S_{equ}$ (Equivalent Stress)

$\sigma \neq 0$

Strength Distribution: Largest Extreme Value

M, ß: Depend on the material and the operating conditions

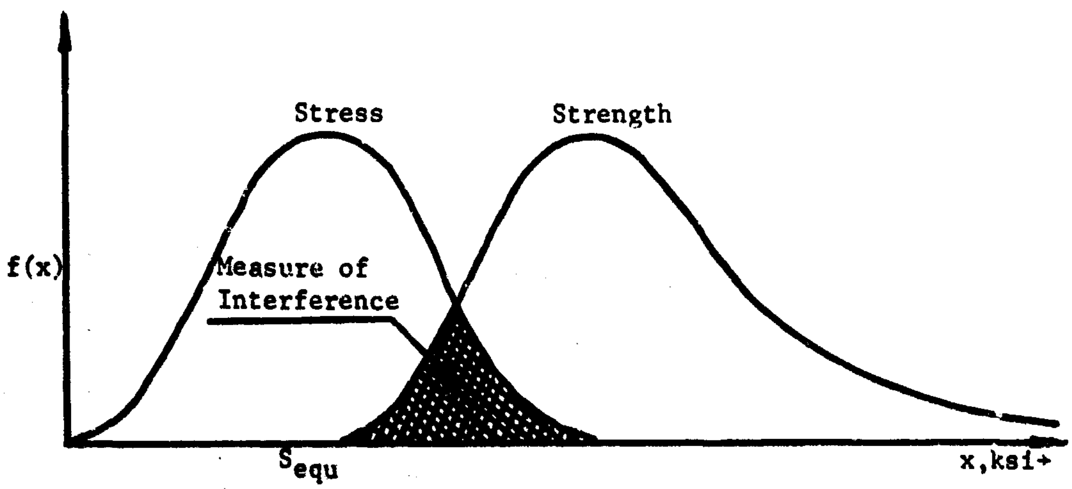


Figure A-2.6 Interference with Standard Deviation of Stress Not Equal to Zero

$\alpha = \beta\sigma,\ \gamma = \beta(\mu - M)$

γ * α	0.001	0.005	0.010	0.025	0.050	0.075	0.100	0.200	0.300	0.400
0.	.3679	.3679	.3679	.3679	.3679	.3679	.3679	.3679	.3682	.3688
-1.	.0660	.0660	.0660	.0661	.0664	.0669	.0675	.0719	.0789	.0877
-2.	.0006	.0006	.0006	.0006	.0007	.0007	.0008	.0013	.0024	.0044
-3.	.0	.0	.0	.0	.0	.0	.0	.0000	.0000	.0000

For $\alpha = 0$, Interference $= e^{-e^{-\gamma}}$

$\alpha = \beta\sigma,\ \gamma = \beta(\mu - M)$

γ * α	0.500	0.600	0.700	0.800	0.900	1.000	1.100	1.200	1.300	1.400
0.	.3699	.3714	.3735	.3760	.3787	.3818	.3849	.3881	.3914	.3946
-1.	.0980	.1092	.1210	.1330	.1451	.1570	.1687	.1800	.1909	.2014
-2.	.0075	.0116	.0170	.0235	.0310	.0392	.0481	.0575	.0672	.0771
-3.	.0001	.0003	.0008	.0017	.0032	.0054	.0083	.0119	.0162	.0212
-4.	.0000	.0000	.0000	.0000	.0001	.0004	.0008	.0015	.0026	.0041
-5.	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0003	.0005
-6.	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0000

For $\sigma = 0$, Interference $= e^{-e^{-\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

γ \ α	1.500	1.600	1.700	1.800	1.900	2.000	2.100	2.200	2.300	2.400
0.	.3977	.4008	.4038	.4067	.4095	.4122	.4147	.4172	.4195	.4218
-1.	.2115	.2211	.2303	.2391	.2474	.2554	.2629	.2701	.2769	.2834
-2.	.0871	.0970	.1069	.1167	.1263	.1357	.1448	.1537	.1623	.1706
-3.	.0268	.0329	.0395	.0463	.0535	.0609	.0684	.0760	.0836	.0912
-4.	.0060	.0084	.0113	.0147	.0185	.0228	.0274	.0323	.0375	.0429
-5.	.0010	.0016	.0025	.0037	.0052	.0070	.0092	.0117	.0145	.0177
-6.	.0001	.0002	.0004	.0007	.0012	.0018	.0026	.0036	.0048	.0063
-7.	.0000	.0000	.0001	.0001	.0002	.0004	.0006	.0009	.0014	.0020
-8.	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	.0003	.0005
-9.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
-10.	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

For $\sigma = 0$, Interference $= e^{-e^{-\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

γ \ α	2.500	2.600	2.700	2.800	2.900	3.000	3.500	4.000	4.500	5.000
0.	.4240	.4260	.4280	.4299	.4317	.4334	.4410	.4472	.4523	.4565
-1.	.2896	.2955	.3011	.3065	.3116	.3165	.3378	.3550	.3691	.3808
-2.	.1787	.1865	.1940	.2013	.2083	.2150	.2453	.2705	.2916	.3094
-3.	.0988	.1063	.1137	.1210	.1282	.1353	.1683	.1973	.2225	.2444
-4.	.0485	.0543	.0603	.0663	.0723	.0784	.1087	.1374	.1638	.1876
-5.	.0211	.0248	.0287	.0329	.0372	.0417	.0660	.0913	.1162	.1397
-6.	.0081	.0100	.0123	.0147	.0174	.0203	.0375	.0578	.0793	.1009
-7.	.0027	.0036	.0047	.0050	.0074	.0090	.0200	.0347	.0520	.0706
-8.	.0008	.0011	.0016	.0022	.0028	.0037	.0099	.0198	.0328	.0479
-9.	.0002	.0003	.0005	.0007	.0010	.0014	.0046	.0107	.0199	.0313
-10.	.0000	.0001	.0001	.0002	.0003	.0005	.0020	.0055	.0115	.0198
-11.	.0000	.0000	.0000	.0001	.0001	.0001	.0008	.0027	.0064	.0121
-12.	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0012	.0034	.0072
-13.	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0005	.0017	.0041
-14.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0008	.0023
-15.	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0004	.0012
-16.	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0002	.0006
-17.	.0	.0	.0	.0	.0	.0000	.0000	.0000	.0001	.0003
-18.	.0	.0	.0	.0	.0	.0	.0000	.0000	.0000	.0001
-19.	.0	.0	.0	.0	.0	.0	.0000	.0000	.0000	.0001
-20.	.0	.0	.0	.0	.0	.0	.0	.0000	.0000	.0000

For $\alpha = 0$, Interference $= e^{-e^{-\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

$\alpha = \beta\sigma,\ \gamma = \beta(\mu - M)$

γ \ α	5.500	6.000	6.500	7.000	7.500	8.000	8.500	9.000	9.500	10.000
0.	.4601	.4632	.4658	.4681	.4701	.4719	.4735	.4749	.4762	.4773
-1.	.3907	.3991	.4064	.4127	.4182	.4231	.4274	.4313	.4348	.4380
-2.	.3246	.3377	.3490	.3589	.3677	.3754	.3824	.3886	.3942	.3993
-3.	.2635	.2802	.2949	.3078	.3194	.3296	.3388	.3471	.3547	.3615
-4.	.2089	.2280	.2450	.2602	.2739	.2862	.2973	.3074	.3166	.3250
-5.	.1616	.1817	.2000	.2167	.2319	.2457	.2583	.2699	.2804	.2902
-6.	.1219	.1417	.1604	.1777	.1937	.2085	.2222	.2348	.2464	.2571
-7.	.0895	.1082	.1263	.1434	.1596	.1748	.1891	.2023	.2147	.2262
-8.	.0640	.0808	.0975	.1139	.1297	.1448	.1592	.1727	.1855	.1975
-9.	.0446	.0590	.0739	.0890	.1040	.1185	.1326	.1460	.1589	.1711
-10.	.0302	.0421	.0549	.0684	.0821	.0958	.1092	.1223	.1349	.1470
-11.	.0199	.0293	.0400	.0517	.0639	.0764	.0889	.1014	.1135	.1254
-12.	.0127	.0199	.0286	.0384	.0490	.0602	.0716	.0832	.0947	.1061
-13.	.0079	.0132	.0200	.0280	.0370	.0468	.0570	.0676	.0783	.0890
-14.	.0048	.0086	.0137	.0201	.0275	.0359	.0449	.0543	.0641	.0740
-15.	.0028	.0054	.0092	.0142	.0202	.0271	.0349	.0432	.0520	.0611
-16.	.0016	.0034	.0061	.0098	.0146	.0203	.0268	.0340	.0418	.0500
-17.	.0009	.0020	.0039	.0067	.0103	.0149	.0203	.0265	.0333	.0406
-18.	.0005	.0012	.0025	.0044	.0072	.0108	.0153	.0204	.0262	.0326
-19.	.0002	.0007	.0015	.0029	.0050	.0078	.0113	.0156	.0205	.0260

For $\alpha = 0$, Interference $= e^{-e^{-\gamma}}$

(Continued on the next Table.)

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

γ \ α	5.500	6.000	6.500	7.000	7.500	8.000	8.500	9.000	9.500	10.000
-20.	.0001	.0004	.0009	.0019	.0034	.0055	.0083	.0117	.0159	.0206
-21.	.0001	.0002	.0005	.0012	.0022	.0038	.0060	.0088	.0121	.0161
-22.	.0000	.0001	.0003	.0007	.0015	.0026	.0043	.0065	.0092	.0125
-23.	.0000	.0001	.0002	.0004	.0010	.0018	.0030	.0047	.0069	.0096
-24.	.0000	.0000	.0001	.0003	.0006	.0012	.0021	.0034	.0051	.0074
-25.	.0000	.0000	.0001	.0002	.0004	.0008	.0014	.0024	.0038	.0056
-26.	.0000	.0000	.0000	.0001	.0002	.0005	.0010	.0017	.0028	.0042
-27.	.0000	.0000	.0000	.0001	.0001	.0003	.0007	.0012	.0020	.0031
-28.	.0000	.0000	.0000	.0000	.0001	.0002	.0004	.0008	.0014	.0023
-29.	.0000	.0000	.0000	.0000	.0000	.0001	.0003	.0006	.0010	.0017
-30.	.0	.0000	.0000	.0000	.0000	.0001	.0002	.0004	.0007	.0012
-31.	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0003	.0005	.0009
-32.	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0003	.0006
-33.	.0	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0004
-34.	.0	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0003
-35.	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0002
-36.	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0001	.0001
-37.	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0001
-38.	.0	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0001
-39.	.0	.0	.0	.0	.0000	.0000	.0000	.0000	.0000	.0000

For $\alpha = 0$, Interference $= e^{-e^{-\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - LARGEST EXTREME VALUE

A-2.5 STRESS DISTRIBUTION - NORMAL
STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

A-2.5.1 Stress Standard Deviation = 0

TABLES OF INTERFERENCE [F(X)]

Stress Distribution: Normal

$\mu = S_{equ}$ (Equivalent Stress)

$\sigma = 0$

Strength Distribution: Smallest Extreme Value

M, β Depend on the material and the operating conditions

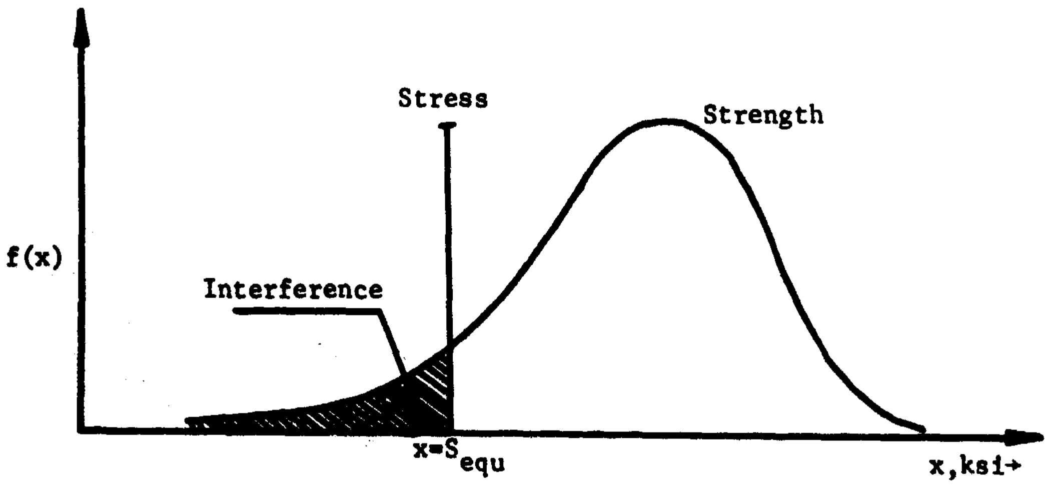


Figure A-2.7 Interference with Standard Deviation of Stress Equal to Zero

Density Function of Smallest Extreme Value is:

$$f(x) = e^{+\beta(x-M)} \cdot e^{-e^{+\beta(x-M)}}$$

Cumulative Distribution Function, $F(x) = \int_{-\infty}^{+x} f(x)\,dx$

Let $y = -e^{+\beta(x-M)}$ $\therefore$ $dy = -\beta e^{+\beta(x-M)}\,dx$

$$F(x=S_{equ}) = \int_{0}^{-e^{+\beta(S_{equ}-M)}} -e^{y}\,dy = -e^{y}\Big|_{0}^{-e^{+\beta(S_{equ}-M)}} = 1 - e^{-e^{+\beta(S_{equ}-M)}}$$

$$F(X) = 1 - e^{-e^{-X}}$$

where $X = -\beta(S_{equ}-M)$

X	Interference F(X)	X	Interference F(X)
0.0	.6321	2.8	.0590
0.1	.5954	2.9	.0540
0.2	.5590	3.0	.0459
0.3	.5233	3.1	.0441
0.4	.4884	3.2	.0400
0.5	.4548	3.3	.0362
0.6	.4224	3.4	.0328
0.7	.3914	3.5	.0298
0.8	.3619	3.6	.0270
0.9	.3341	3.7	.0244
1.0	.3078	3.8	.0221
1.1	.2831	3.9	.0200
1.2	.2601	4.0	.0182
1.3	.2385	4.2	.0149
1.4	.2185	4.4	.0122
1.5	.2000	4.6	.0100
1.6	.1829	4.8	.0082
1.7	.1669	5.0	.0067
1.8	.1524	5.2	.0055
1.9	.1389	5.4	.0045
2.0	.1266	5.6	.0037
2.1	.1153	5.8	.0030
2.2	.1049	6.0	.0025
2.3	.0954	6.2	.0020
2.4	.0868	6.4	.0017
2.5	.0788	6.6	.0014
2.6	.0716	6.8	.0011
2.7	.0650		

STRESS DISTRIBUTION - NORMAL (σ=0)

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

A-2.5.2 Stress Standard Deviation $\neq 0$

TABLES OF INTERFERENCE

Stress Distribution: Normal

Strength Distribution: Smallest Extreme Value

$\mu = S_{equ}$	(Equivalent Stress)	M	Depend on the material and the
$\sigma \neq 0$		β	operating conditions

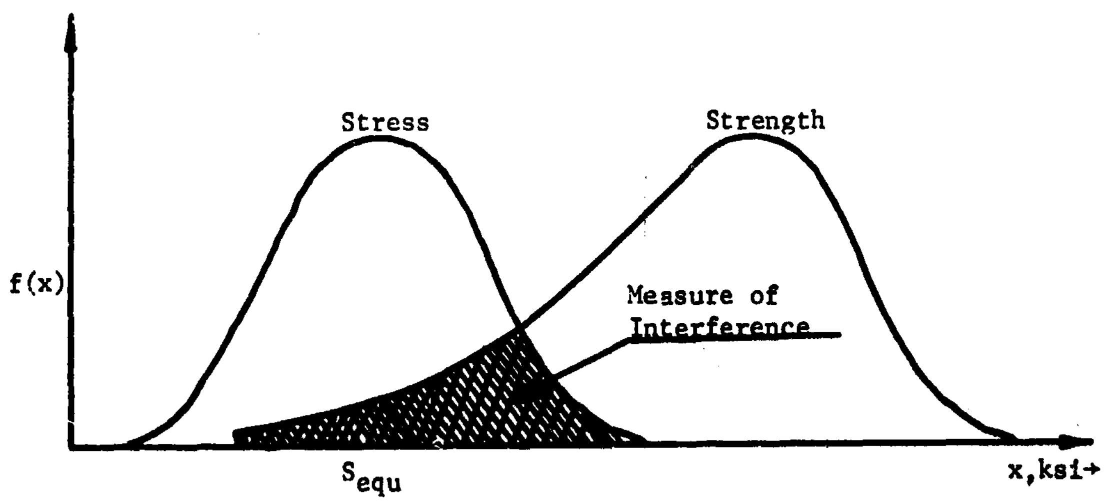


Figure A-2.8 Interference with Standard Deviation of Stress Not Equal to Zero

γ	* α	0.001	0.005	0.010	0.025	0.050	0.075	0.100	0.200	0.300	0.400
0.	*	.6321	.6321	.6321	.6321	.6321	.6321	.6321	.6321	.6318	.6312
-1.	*	.3078	.3078	.3078	.3079	.3080	.3083	.3086	.3110	.3148	.3200
-2.	*	.1266	.1266	.1266	.1266	.1267	.1269	.1271	.1286	.1312	.1348
-3.	*	.0486	.0486	.0486	.0486	.0486	.0487	.0488	.0495	.0506	.0523
-4.	*	.0182	.0182	.0182	.0182	.0182	.0182	.0182	.0185	.0190	.0196
-5.	*	.0067	.0067	.0067	.0067	.0067	.0067	.0068	.0069	.0070	.0073
-6.	*	.0025	.0025	.0025	.0025	.0025	.0025	.0025	.0025	.0026	.0027
-7.	*	.0009	.0009	.0009	.0009	.0009	.0009	.0009	.0009	.0010	.0010
-8.	*	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0004	.0004
-9.	*	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
-10.	*	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
-11.	*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

For $\alpha = 0$, Interference $= 1 - e^{-e^{\gamma}}$

γ	* α	0.500	0.600	0.700	0.800	0.900	1.000	1.100	1.200	1.300	1.400
0.	*	.6301	.6286	.6265	.6240	.6213	.6182	.6151	.6119	.6086	.6054
-1.	*	.3263	.3333	.3409	.3487	.3565	.3641	.3714	.3782	.3847	.3907
-2.	*	.1394	.1451	.1517	.1592	.1674	.1761	.1853	.1948	.2043	.2139
-3.	*	.0544	.0572	.0605	.0644	.0691	.0743	.0802	.0868	.0938	.1013
-4.	*	.0205	.0216	.0230	.0246	.0267	.0290	.0318	.0351	.0388	.0430
-5.	*	.0076	.0080	.0086	.0092	.0100	.0110	.0121	.0135	.0151	.0170
-6.	*	.0028	.0030	.0032	.0034	.0037	.0041	.0045	.0050	.0057	.0065
-7.	*	.0010	.0011	.0012	.0013	.0014	.0015	.0017	.0019	.0021	.0024
-8.	*	.0004	.0004	.0004	.0005	.0005	.0006	.0006	.0007	.0008	.0009
-9.	*	.0001	.0002	.0002	.0002	.0002	.0002	.0002	.0003	.0003	.0003
-10.	*	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
-11.	*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

For $\alpha = 0$, Interference $= 1 - e^{-e^{\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

$\alpha = \beta\sigma$, $\gamma = \beta(\mu - M)$

γ \ α	1.500	1.600	1.700	1.800	1.900	2.000	2.100	2.200	2.300	2.400
0.	.6023	.5992	.5962	.5933	.5905	.5878	.5853	.5828	.5805	.5782
-1.	.3963	.4014	.4062	.4106	.4147	.4184	.4219	.4251	.4281	.4309
-2.	.2233	.2324	.2413	.2499	.2582	.2661	.2737	.2809	.2878	.2943
-3.	.1092	.1174	.1257	.1341	.1426	.1510	.1594	.1676	.1757	.1836
-4.	.0477	.0523	.0583	.0642	.0705	.0769	.0836	.0905	.0975	.1045
-5.	.0192	.0218	.0247	.0280	.0316	.0356	.0399	.0445	.0494	.0545
-6.	.0074	.0085	.0098	.0114	.0132	.0152	.0176	.0202	.0230	.0262
-7.	.0028	.0032	.0038	.0044	.0052	.0061	.0072	.0085	.0100	.0117
-8.	.0010	.0012	.0014	.0017	.0020	.0024	.0029	.0034	.0041	.0049
-9.	.0004	.0004	.0005	.0006	.0007	.0009	.0011	.0013	.0016	.0020
-10.	.0001	.0002	.0002	.0002	.0003	.0003	.0004	.0005	.0006	.0008
-11.	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0002	.0003
-12.	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001
-13.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

For $\alpha = 0$, Interference $= 1-e^{-e^{\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

α = βσ, γ = β(μ-M)

γ	α: 2.500	2.600	2.700	2.800	2.900	3.000	3.500	4.000	4.500	5.000
0.	.5760	.5740	.5720	.5701	.5683	.5666	.5590	.5528	.5477	.5435
-1.	.4335	.4359	.4382	.4403	.4423	.4441	.4519	.4579	.4625	.4663
-2.	.3006	.3065	.3121	.3175	.3227	.3275	.3487	.3655	.3791	.3904
-3.	.1913	.1987	.2060	.2130	.2198	.2263	.2559	.2805	.3011	.3185
-4.	.1116	.1187	.1257	.1326	.1395	.1463	.1783	.2067	.2315	.2530
-5.	.0598	.0653	.0709	.0767	.0825	.0883	.1173	.1459	.1719	.1954
-6.	.0296	.0332	.0371	.0412	.0454	.0499	.0737	.0987	.1233	.1467
-7.	.0136	.0157	.0181	.0206	.0234	.0263	.0436	.0638	.0853	.1068
-8.	.0059	.0070	.0083	.0097	.0113	.0131	.0245	.0395	.0569	.0756
-9.	.0024	.0029	.0036	.0043	.0051	.0061	.0130	.0234	.0366	.0518
-10.	.0010	.0012	.0015	.0018	.0022	.0027	.0066	.0132	.0227	.0345
-11.	.0004	.0005	.0006	.0007	.0009	.0012	.0032	.0072	.0135	.0222
-12.	.0001	.0002	.0002	.0003	.0004	.0005	.0015	.0037	.0078	.0139
-13.	.0001	.0001	.0001	.0001	.0001	.0002	.0006	.0019	.0043	.0084
-14.	.0000	.0000	.0000	.0000	.0001	.0001	.0003	.0009	.0023	.0049
-15.	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0004	.0012	.0028
-16.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0006	.0015
-17.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0003	.0008
-18.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0004
-19.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0002
-20.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
-21.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
-22.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

For $\sigma = 0$, Interference = $1-e^{-e^{\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

$\alpha = \beta\sigma,\ \gamma = \beta(\mu - M)$

γ \ α	5.500	6.000	6.500	7.000	7.500	8.000	8.500	9.000	9.500	10.000
0.	.5399	.5369	.5342	.5319	.5299	.5281	.5265	.5251	.5238	.5227
-1.	.4693	.4719	.4740	.4759	.4775	.4789	.4802	.4813	.4822	.4831
-2.	.3997	.4077	.4145	.4204	.4255	.4300	.4340	.4376	.4408	.4437
-3.	.3332	.3459	.3568	.3664	.3748	.3822	.3888	.3947	.4001	.4049
-4.	.2717	.2880	.3023	.3149	.3261	.3361	.3451	.3531	.3604	.3670
-5.	.2164	.2352	.2519	.2669	.2803	.2924	.3033	.3132	.3221	.3303
-6.	.1683	.1882	.2064	.2229	.2379	.2515	.2639	.2753	.2857	.2952
-7.	.1278	.1476	.1661	.1833	.1992	.2139	.2274	.2398	.2513	.2620
-8.	.0945	.1133	.1313	.1485	.1646	.1797	.1939	.2070	.2193	.2307
-9.	.0682	.0851	.1019	.1184	.1342	.1493	.1636	.1771	.1898	.2017
-10.	.0480	.0625	.0776	.0929	.1079	.1225	.1365	.1500	.1628	.1750
-11.	.0329	.0450	.0580	.0717	.0855	.0992	.1127	.1258	.1385	.1506
-12.	.0219	.0316	.0426	.0544	.0668	.0794	.0920	.1045	.1167	.1286
-13.	.0142	.0217	.0306	.0406	.0514	.0627	.0743	.0860	.0975	.1090
-14.	.0090	.0146	.0216	.0298	.0390	.0489	.0593	.0700	.0808	.0916
-15.	.0056	.0096	.0149	.0215	.0292	.0377	.0468	.0564	.0663	.0763
-16.	.0033	.0062	.0101	.0153	.0215	.0286	.0365	.0450	.0539	.0631
-17.	.0019	.0039	.0067	.0107	.0156	.0215	.0281	.0355	.0434	.0517
-18.	.0011	.0024	.0044	.0073	.0111	.0159	.0214	.0277	.0346	.0421
-19.	.0006	.0014	.0028	.0049	.0078	.0116	.0161	.0214	.0274	.0339

For $\alpha = 0$, Interference $= 1-e^{-e^{\gamma}}$

(Continued on the next Table.)

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

$\alpha = \beta\sigma, \ \gamma = \beta(\mu - M)$

γ \ α	5.500	6.000	6.500	7.000	7.500	8.000	8.500	9.000	9.500	10.000
-20.	.0003	.0008	.0018	.0033	.0054	.0083	.0120	.0164	.0214	.0271
-21.	.0002	.0005	.0011	.0021	.0037	.0059	.0088	.0124	.0166	.0215
-22.	.0001	.0003	.0006	.0014	.0025	.0042	.0064	.0093	.0128	.0169
-23.	.0000	.0001	.0004	.0008	.0016	.0029	.0046	.0069	.0097	.0131
-24.	.0000	.0001	.0002	.0005	.0011	.0020	.0033	.0050	.0073	.0101
-25.	.0000	.0000	.0001	.0003	.0007	.0013	.0023	.0037	.0055	.0078
-26.	.0000	.0000	.0001	.0002	.0004	.0009	.0016	.0026	.0040	.0059
-27.	.0000	.0000	.0000	.0001	.0003	.0006	.0011	.0019	.0030	.0044
-28.	.0000	.0000	.0000	.0001	.0002	.0004	.0007	.0013	.0021	.0033
-29.	.0000	.0000	.0000	.0000	.0001	.0002	.0005	.0009	.0015	.0024
-30.	.0000	.0000	.0000	.0000	.0001	.0001	.0003	.0006	.0011	.0018
-31.	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0004	.0008	.0013
-32.	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0003	.0005	.0009
-33.	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0004	.0007
-34.	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0003	.0005
-35.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0002	.0003
-36.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
-37.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0002
-38.	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
-39.	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001
-40.	.0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

For $\alpha = 0$, Interference $= 1-e^{-e^{\gamma}}$

STRESS DISTRIBUTION - NORMAL

STRENGTH DISTRIBUTION - SMALLEST EXTREME VALUE

APPENDIX 3 EVALUATION OF THE INTEGRALS BY NUMERICAL ANALYSIS

APPENDIX 3 EVALUATION OF THE INTEGRALS BY NUMERICAL ANALYSIS

A-3.1 THE PROBLEM

In this report stress/strength interference theory was used to predict failure probabilities for several important cases not included in [1]. The two cases of interest here are (1) the smallest extreme value distributed strength and normally distributed stress and (2) the largest extreme value distributed strength and normally distributed stress. The integral

$$\Pr[\text{Failure}] = \Pr(X \leq Y) = \int_{-\infty}^{+\infty} F(y)g(y)dy \tag{1}$$

was evaluated where $F(\cdot)$ is the distribution function of X (the random variable associated with the strength) and $g(\cdot)$ is the density function of Y (the random variable associated with the stress). That is, we suppose that Y has a probability density function:

$$g_Y(y) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy, \quad -\infty \leq y \leq +\infty \tag{2}$$

and X has a probability distribution function

$$F_X(x) = 1-e^{-e^{\beta(x-M)}}, \quad -\infty \leq x \leq +\infty \tag{3}$$

if it is distributed as the smallest extreme value. If X is distributed as the largest extreme value, its probability distribution function is:

$$F_X(x) = e^{-e^{-\beta(x-M)}}, \quad -\infty \leq x \leq +\infty \tag{4}$$

One sees that if $z = 1-F_X(x)$ is plotted on a lnln scale it will be linearly related to x on an arithmetic scale as

$$z = \beta(x-M) \quad \text{or} \quad z = -\beta(x-M)$$

Hence one can call M the mode of the distribution and β (or $-\beta$) the "slope" or "shape" parameter.

Inserting (2) and (3) or (4) into (1) will give (5) or (6).

$$\Pr(X \leq Y) = \int_{-\infty}^{+\infty} \left[1-e^{-e^{\beta(y-M)}}\right] \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(y-\mu)^2}{2\sigma^2}} dy \tag{5}$$

$$\Pr(X \leq Y) = \int_{-\infty}^{+\infty} \left[e^{-e^{-\beta(y-M)}} \right] \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(y-\mu)^2}{2\sigma^2}} dy \tag{6}$$

A-3.2 SIMPLIFICATION OF THE EQUATIONS

Equations (5) and (6) are quite difficult to work with numerically since each one involves four parameters. It is desirable to define a new variable of integration and new parameters. To this end we let:

$$u = \frac{y-\mu}{\sigma}, \quad \alpha = \beta\sigma, \text{ and } \gamma = \beta(\mu - M)$$

Then (5) of Section A-3.1 becomes

$$\Pr(X \leq Y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} \frac{dy}{\sigma} - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-e^{\beta(u\sigma+\mu-M)}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} \frac{dy}{\sigma},$$

and this further reduces to

$$\Pr(X \leq Y) = 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-e^{\alpha u+\gamma}} e^{-\frac{1}{2}u^2} du \tag{7}$$

Also, (6) of Section A-3.1 becomes

$$\Pr(X \leq Y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-e^{-(\alpha u+\gamma)}} e^{-\frac{1}{2}u^2} du \tag{8}$$

Inspection of (7) and (8) will show that the integral to be calculated is of the same form in each case except that the uppermost exponent is negative in the Largest Extreme Value case. Therefore, to further isolate the numerical analysis problem involved, define new constants A and G such that for (7), the Normal-Smallest Extreme Value integral,

$$A = \alpha \text{ and } G = \gamma,$$

but for (8), the Normal-Largest Extreme Value integral,

$$A = -\alpha \text{ and } G = -\gamma$$

Then, the calculation of the probabilities given by Equations (5) and (6) of Section A-3.1 reduces essentially to the integration of

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{1}{2}u^2} e^{-e^{Au+G}} du \tag{9}$$

Since this integral does not exist in closed form, numerical techniques must be employed. The ranges of α and γ of practical interest and the associated values of A and G are

$A = \pm\alpha$ where α ranges: .001,.005,.010,.025,.05,.075,.1,.2,... 3., 3.5,... 9.5,10

$G = \pm\gamma$ where γ ranges: 0.,-1.,... -40

Note that α itself is always positive and γ is always negative (or zero). A negative α would imply a negative standard deviation. This situation is without mathematical meaning. If γ were positive, the material in question would have a mean strength less than the mode of the stress. Such a situation is of dubious engineering importance. (β is always positive.)

Note, also, that for the Normal-Smallest Extreme Value case, the probability of failure is <u>one minus</u> the number given by (9).

A-3.3 NUMERICAL METHODS CONSIDERED FOR THE PROBLEM

The integral (9) of the previous section could be evaluated in several ways. Its form immediately suggests Gaussian-Hermite integration. This method can be summarized as follows:

Let $F(u) = e^{-e^{Au+G}}$ and define $v = u/\sqrt{2}$,

then $$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} e^{-\frac{1}{2}u^2} \cdot F(u)du = \frac{1}{\sqrt{\pi}}\int_{-\infty}^{+\infty} e^{-v^2} F(v)dv$$

and by the Gaussian-Hermite formulation,

$$\frac{1}{\sqrt{\pi}}\int_{-\infty}^{+\infty} e^{-v^2} F(v)dv = \frac{1}{\sqrt{\pi}}\sum_{i=1}^{n} A_i F(v_i)$$

where the arguments v_i are the zeros of the nth Hermite polynomial

$$H_n(v) = (-1)^n e^{v^2} \frac{d^n}{dv^n} (e^{-v^2})$$

and the coefficients A_i are

$$A_i = \frac{2^{n+1} n!\sqrt{\pi}}{[H_n'(v_i)]^2}$$

The numbers v_i and A_i are available in tables. The approximation error using this method depends on the higher derivatives of F. For the n-point case,

$$\text{error} = \frac{n!\sqrt{\pi}\, F^{(2n)}(\xi)}{2^n (2n)!}\ , \quad -\infty < \xi < +\infty$$

(The formula for computing the higher derivatives of F is given in Table A-3.1)

Errors in integrating (9) of Section A-3.2 were computed for the n = 2, 4, and 8 point formulas for the entire range of the parameters. It was found that the n = 8 formulas would give acceptable errors for small |A| and large |G|. Theoretically at least, this scheme could be used to integrate (9) for any A and G if the number of points taken were sufficiently large.

Despite its advantages, the Gaussian-Hermite integration method was not used to prepare the tables of this report for the following reasons:

i) The higher derivatives of F become quite difficult to compute and hence the errors involved are difficult to evaluate.

ii) It proved useful for most values of the parameters for which the approach presented below proved even simpler.

iii) It was decided that using only one method (that below) was more efficient than programming different methods for different values of A and G.

If users of the tables wish to compute probabilities of failure for α's and γ's not included in this report, the Gaussian-Hermite method may prove acceptable, but the method employed here is recommended.

The tables of probabilities included in this report were generated by a FORTRAN program run on the University of Michigan's IBM 360/67. For every α and γ, the program:

i) Determined limits of integration following the logic of Section A-3.5,

ii) Used Simpson's rule to integrate (9) within these limits, and

iii) Added to the above value the integral of the normal curve neglected by using the calculated limits.

This approach is illustrated in Figure A-3.1. Its major advantages, which will be made clearer in later sections, can be listed as

i) Automatically preventing computing difficulties by limiting the exponentials to be computed to acceptable values,

ii) Having an easily computed error,

iii) Reducing computing time by using the error function subroutine wherever possible and by automatically recognizing where the integral is approximately zero, and

DERIVATIVES OF $e^{-e^{Au+G}}$

$$F = e^{-e^{Au+G}}, \qquad P = -e^{Au+G}$$

$$F^{(1)} = A^1 F\,[P^1]$$
$$F^{(2)} = A^2 F\,[P^1 + P^2]$$
$$F^{(3)} = A^3 F\,[P^1 + 3\,P^2 + P^3]$$
$$F^{(4)} = A^4 F\,[P^1 + 7\,P^2 + 6\,P^3 + P^4]$$
$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$
$$F^{(n)} = A^n F\,[C_{1_n} P^1 + C_{2_n} P^2 + \ldots C_{k_n} P^k + \ldots C_{n_n} P^n]$$

If we let $C_{(n+1)_n} = 0$, then the kth coefficient is given by

$$C_{k_n} = k \cdot C_{k_{(n-1)}} + C_{(k-1)_{(n-1)}}$$

FOURTH DERIVATIVE OF $e^{-\frac{1}{2}u^2 - e^{Au+G}}$

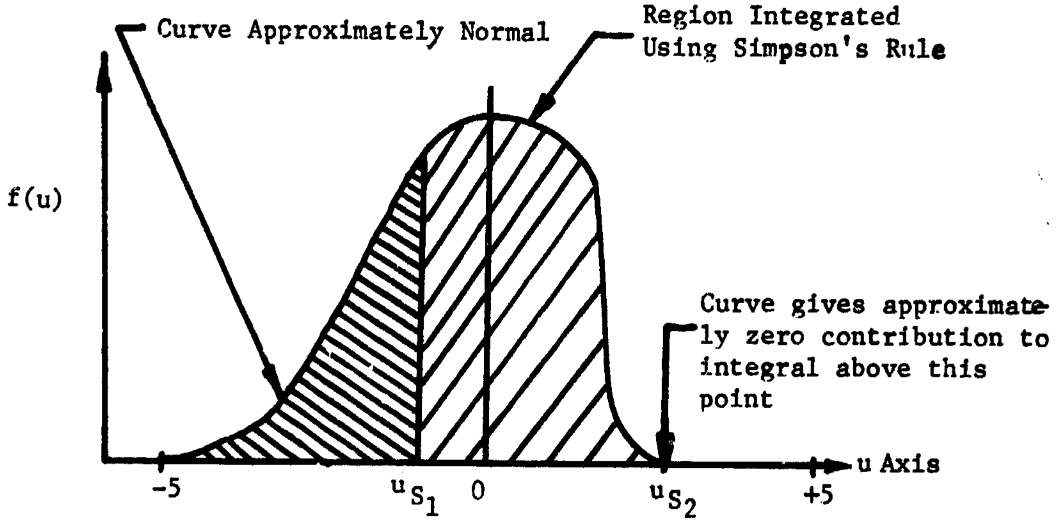
$$U = e^{-\frac{1}{2}u^2 - e^{Au+G}}, \qquad F = e^{-e^{Au+G}}$$

$$U^{IV} = e^{-\frac{1}{2}u^2}\left[(3-6u^2+u^4)F + (12u-4u^3)F^{(1)} + (-6+6u^2)F^{(2)} + (-4u)F^{(3)} + F^{(4)}\right]$$

$$\begin{aligned}U^{IV} = U \Big\{ (3-6u^2+u^4) &+ \\ &(-e^{Au+G})[A(12u-4u^3) + A^2(-6+6u^2) + A^3(-4u) + A^4] \\ &(+e^{2(Au+G)})[A^2(-6+6u^2) + 3A^3(-4u) + 7A^4] \\ &(-e^{3(Au+G)})[A^3(-4u) + 6A^4] \\ &(+e^{4(Au+G)})[A^4]\Big\}\end{aligned}$$

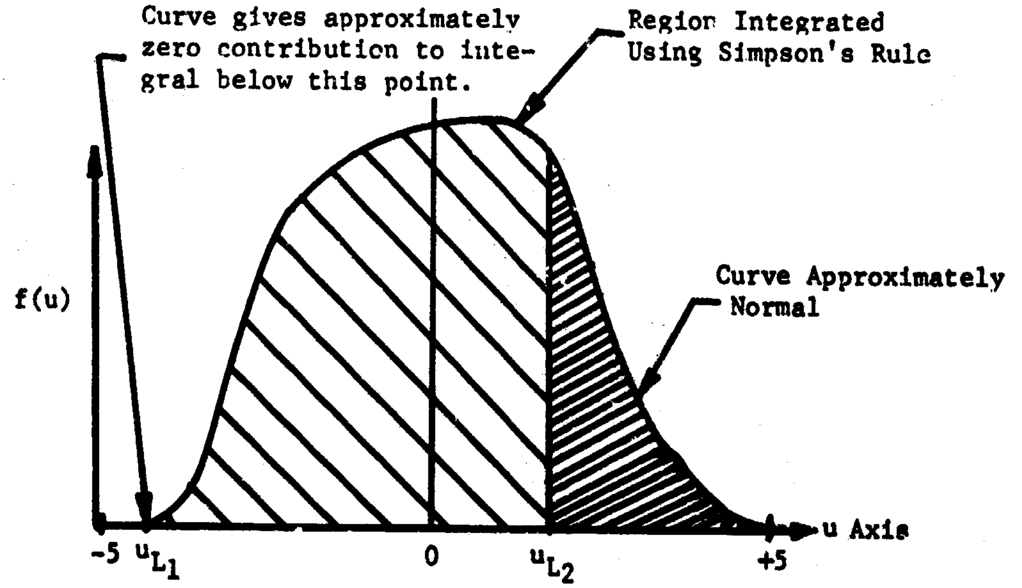
Table A-3.1 Expressions for U^{IV} and $F^{(n)}$

Normal-Smallest Extreme Value



PR(Failure) = 1.-(total area under curve)

Normal-Largest Extreme Value



PR(Failure) = (Total area under curve)

Figure A-3.1 Limits of Integration

iv) Being applicable to any range of A and G simply by changing the Simpson's integration step-size.

A-3.4 SIMPLIFYING APPROXIMATIONS

The functions comprising the integrand of (9) of Section A-3.2 are quite well behaved and bounded between 0 and 1. Their exponential form leads to a number of important approximations. Let U equal the integrand of (9) and note that U is the product of the normal curve and a "double exponential."

The integral of the normal curve is equal to 1 within $.5734 \times 10^{-6}$ over the interval -5 to +5. Therefore, since

$$0 \le e^{-e^{Au+G}} \le 1 \text{ implies } \left(\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2}\right) e^{-e^{Au+G}} \le \left(\frac{1}{\sqrt{2\pi}} \cdot e^{-\frac{1}{2}u^2}\right),$$

$$\int_{-\infty}^{+\infty} U du \cong \int_{-5}^{+5} U du \qquad \text{to at least 6 places.} \qquad (10)$$

Let $F = e^{-e^{Au+G}}$

If the function F differs from one over some interval $[u_1, u_2]$ by less than 5×10^{-5}, then the integral (10) can be evaluated to four places simply by integrating the normal curve (actually the FORTRAN error function subroutine was used). That is,

$$\int_{u_1}^{u_2} \left(\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2}\right)(1-.00005)du \cong \int_{u_1}^{u_2} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} du \text{ where the}$$

$$\text{worst error} = .0005 \times \int_{-5}^{+5} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} du = .0005$$

The combination of u, A, and G which causes F to be within 5×10^{-5} of one is easily determined:

$$e^{-e^{Au+G}} > .99995$$

$$\text{for} \quad e^{Au+G} < 5 \times 10^{-5}$$

$$\text{Take} \quad e^{Au+G} < 1 \times 10^{-5}$$

$$\text{Then} \quad \boxed{Au+G < -11.5} \qquad (11)$$

If the function F differs from zero over the interval [-5,+5] by less than 5×10^{-5}, then the integral can be approximated as zero to four places. The above argument concerning the error applies here also; that is, the

integral differs from zero by less than 5×10^{-5} when F differs from zero by less than 5×10^{-5}. It will prove useful to know the value of the upper exponent for which this occurs.

$$e^{-e^{Au+G}} < .00005$$

$$\text{Take} \quad e^{-e^{Au+G}} < 1 \times 10^{-5}$$

$$-e^{Au+G} < -11.5$$

$$Au+G > \ln 11.5$$

$$\boxed{Au+G > 2.44} \qquad (12)$$

A-3.5 LIMITS OF INTEGRATION

Equation (10) defined the limits of integration for our problem as -5 to +5. The discussion below shows that it is possible to further isolate the interval on the u-axis in which numerical integration of (9) is necessary.

A-3.5.1 <u>Limits for Normal-Smallest Extreme Value Case</u>

For a given A and G, expression (11) defines a u-value, call it u_{s_1}, below which the integrand can be approximated as a normal curve.

$$u_{s_1} = \frac{-G-11.5}{A}$$

Likewise (12) defines a u, say u_{s_2}, above which the contribution to the integral is zero.

$$u_{s_2} = \frac{-G+2.44}{A}$$

Therefore, numerical integration need only be used on $[u_{s_1}, u_{s_2}]$. This is illustrated in Figure A-3.1. In some instances u_{s_1} and u_{s_2} may be outside the -5 to +5 limits established by (10). The limits should then be taken as -5 to +5. Note that:

When $u_{s_1} > +5$ the integrand can be approximated to sufficient accuracy by considering it to be the normal density function.

When $u_{s_2} < -5$ the integrand can be approximated by considering it equal to zero.

A-3.5.2 <u>Limits for Normal-Largest Extreme Value Case</u>

The results of the previous article apply here directly except that for this case $A = -\alpha$ (recall that α is always positive) and the senses of both

(11) and (12) are reversed. This makes

$$u_{L_1} = \frac{-G+2.44}{A}$$

and for $u < u_{L_1}$ the integral is "zero".

also, $$u_{L_2} = \frac{-G-11.5}{A}$$

and for $u > u_{L_2}$ the curve is "normal".

When $u_{L_1} > +5$ the entire curve is "zero".

When $u_{L_2} < -5$ the entire curve is "normal".

Of course, in those situations where $u_{L_1} < -5$, the lower limit should be taken as -5 and where $u_{L_2} > +5$, the upper limit becomes +5.

A-3.6 DETERMINATION OF SIMPSON'S RULE STEP-SIZE

The truncation error for Simpson's integration scheme is given by

$$|\text{Error}| = \frac{(u_2-u_1)}{180} U^{IV}(\xi)(\Delta u)^4, \quad u_1 \le \xi \le u_2 \,. \tag{13}$$

The fourth derivative in this expression should be evaluated at the ξ which makes U^{IV} a maximum. The complexity of U^{IV} (shown in Table A-3.1) made a complete analysis of its behavior impossible. Study of the form of U^{IV} together with careful scrutiny of a large number of computed values gave what was believed to be good estimates for the maximum of U^{IV} for all combinations of A and G. These values were substituted into (13) and Δu's were determined assuming a desired error of less than 5×10^{-5}.

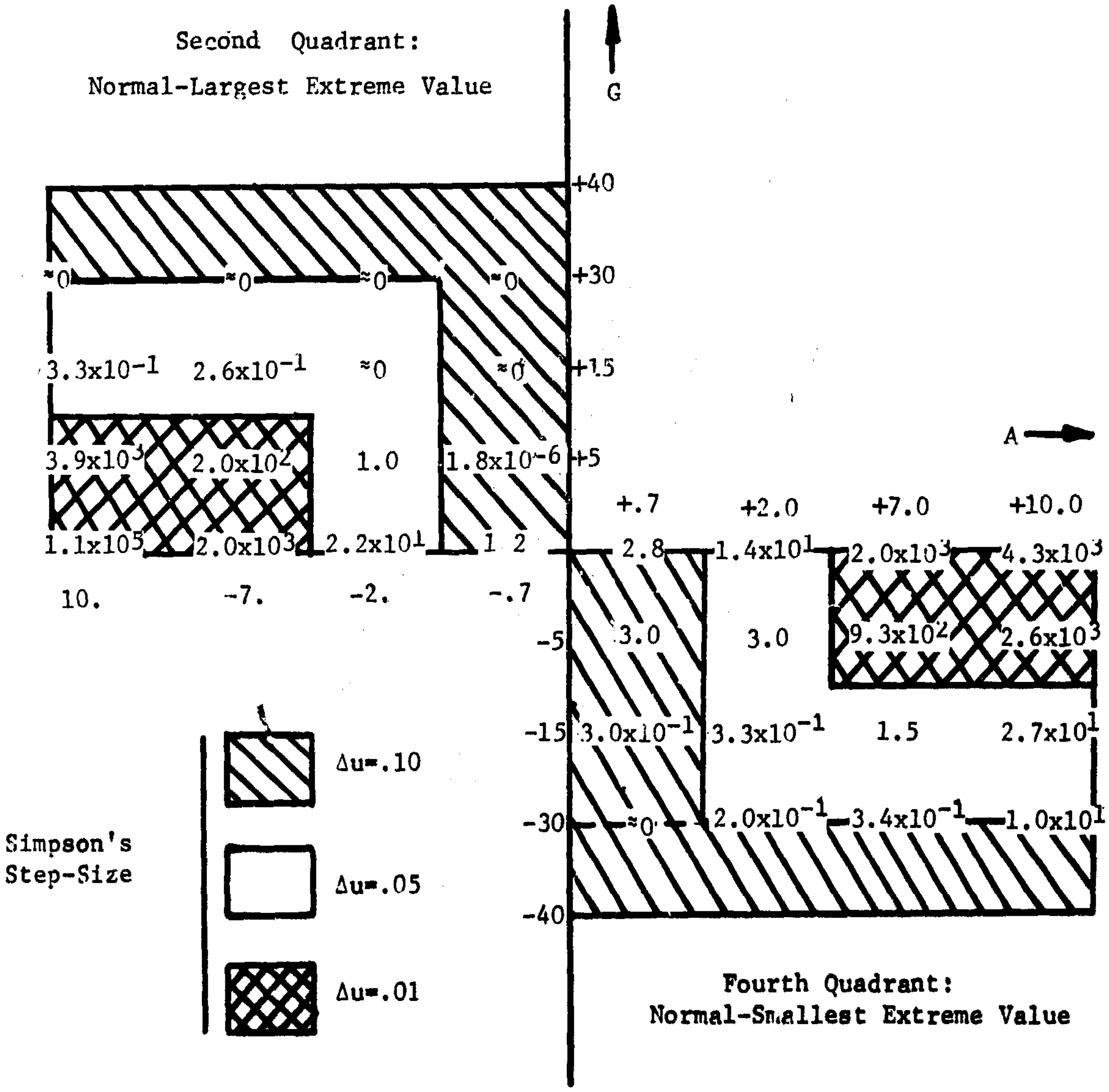
Actually, only three Δu's were used: .1, .05, and .01. Although the decision of which to use for a given set of the parameters was based upon inspection of calculated values of U^{IV}, an understanding of the behavior of U^{IV}_{max} with changes in A and G is important. The double exponential coefficient of U^{IV} will damp out any influence by the other exponentials to make U^{IV} large. For $A \to 0$, U^{IV} will be small. In fact, for A small, U^{IV} should behave similarly to the fourth derivative of the normal curve since G only acts as a "scaling factor" and does not effect the "curvature" of U. Tables show the fourth derivative of the normal curve to be approximately 1.

As $A \to 0$, $U^{IV}_{max} \cong 1$, and

$$|5 \times 10^{-5}| = \frac{[+5-(-5)]}{180} (1)(\Delta u)^4$$

$$(\Delta u)^4 = 9 \times 10^{-4}$$

$$\Delta u \cong .17$$



Note: U^{IV}_{MAX} is only given for the interval where Simpson's integration was used.

Figure A-3.2 U^{IV}_{MAX} for Various A and G and Simpson's Integration Step-Size

For large $|A|$'s (neglect G) the $U^{IV}{}_{max}$ will behave as A^4. Then for the largest A of interest, $A = 10.0$:

$$(\Delta u)^4 = \frac{9 \times 10^{-4}}{10^4} = 9 \times 10^{-8}$$

$$\Delta u \cong .0017 \; .$$

It can also be seen from the form of U^{IV} that for large $|G|$'s the value of U^{IV} will be driven to zero by one of the exponentials. (Note also that the behavior of U^{IV} is only of interest on that interval where Simpson's integration is to be used.)

Recall that for each of the two cases being studied and for each pair of the parameters α and γ, the integration of (5) or (6) of A-3.1 requires use of Simpson's integration on an interval identified by Section A-3.5. The error produced by the use of Simpson's rule depends on the derivative U^{IV} and the fourth power of the step-size. Figure A-3.2 gives the value of $U^{IV}{}_{max}$ at various points in the A-G plane and shows the regions in the plane where the three step-sizes (.01, .05, and .1) could be used. In the A-G plane, the second quadrant is the region of interest for the Normal-Largest Extreme Value case ($A = -\alpha$, $.001 \leq \alpha \leq 10.$; $G = -\gamma$, $-40. \leq \gamma \leq 0$). The fourth quadrant is the A-G region of interest in the Normal-Smallest Extreme Value case. In Figure A-3.2, choose an abscissa and an ordinate; the number indicated is the maximum of U^{IV} found by calculating U for many u's on the interval in which Simpson's rule was used. The cross-hatching defines the regions where the indicated step-size will maintain the error less than 5×10^{-5}. (These regions were delineated more carefully for the actual computer runs.)

Example:

Assume that we wish to find the probability of failure for the Normal Largest Extreme Value case for $\alpha = .7$ and $\gamma = -5$. For this case, the parameters A and G in the integral (9) of A-3.2 become $A = -\alpha = -.7$ and $G = -\gamma = +5$. Figure A-3.2 shows that for $A = -.7$ and $G = +5$, $U^{IV}{}_{max} \approx 2.0 \times 10^2$. The cross-hatching shows that a step-size of $\Delta u = .01$ is acceptable for the integration.

A-3.7 ERROR ANALYSIS

The possible errors produced in generating the tabulated values are listed below:

Error Source	Maximum Error
Truncation of integral on [-5,+5]	-6×10^{-7}
Approximations of Section A-3.5	-1×10^{-5}
Simpson's integration truncation	$\pm 5 \times 10^{-5}$
Computer round-off	$\pm 1 \times 10^{-7}$
Round-off to 4 places	$\pm 1 \times 10^{-4}$

The tabular values are correct to 2×10^{-4}.

A-3.8 SUMMARY

It was shown that calculation of the probabilities of failure reduces to the numerical evaluation of a single integral. The integral was computed by using Simpson's rule and by employing several approximations.

APPENDIX 4 FLOW CHART OF THE COMPUTER PROGRAM USED FOR DETERMINATION OF THE FATIGUE STRENGTH DISTRIBUTION

APPENDIX 4 FLOW CHART OF THE COMPUTER PROGRAM USED FOR THE DETERMINATION OF THE FATIGUE STRENGTH DISTRIBUTION

A-4.1 EXPLANATION OF THE SYMBOLS USED IN THE FLOW CHART

C_1, C_2, C_3, ..., C_i, ... C_m are the lives at which the distributions of fatigue strength are to be determined. In the present study, these are 10^3, 10^4, $5x10^4$, 10^5, $5x10^5$, 10^6, $5x10^6$, 10^7, and 10^8 cycles.

m is the total number of lives which in this study is equal to 9.

U is the code number for a mode of stress, for example;

U = 0 is for the alternating (completely reversed) stress,
U = 1 is for the maximum stress,
U = 2 is for the range of stress (maximum-minimum).

US is the identification number for the units of stress, for example;

US = 1 is for the units in psi,
US = 2 is for the units in ksi,
US = 3 is for the units in short tons/in^2,
US = 4 is for the units in kilograms/mm^2,
US = 5 is for the units in long tons/in^2.

UL is for the identification number for the units of life, for example;

UL = 1 is for the units in cycles,
UL = 2 is for the units in reversals (two reversals = one cycle),
UL = 3 is for the units in hours where frequency (cycles/hr) was known.

S_m is the mean stress which in the present study was always equal to zero.

S_1, S_2, S_3, ... S_i, ... S_m are the values of the applied stresses, and,

L_1, L_2, L_3, ... L_i, ... L_m are the values of the life to failure corresponding to the above stresses.

i is the subscript to designate the ith data point (for example, L_i and S_i are the coordinates of the ith data point of the S-N type data).

n is the number of data points.

$MR_{n,1}$, $MR_{n,2}$, ..., $MR_{n,n}$ are the median rank values for the sample size of n(for example, $MR_{5,1}$, $MR_{5,2}$, $MR_{5,3}$, $MR_{5,4}$, and $MR_{5,5}$ are the median rank values when n = 5).

$Z_{n,1}$, $Z_{n,2}$, $Z_{n,3}$, ..., $Z_{n,n}$ are the standardized normal variates corresponding to the median ranks of sample size n. (These are also called the median ranks z values as given in Table 6.1 on Page 49).

YW_i is the linear mode variable of the ordinate scale for Weibull distribution for the ith data point, and it is also the same for Smallest Extreme Value distribution (See Equations 6.24 and 6.25 on Pages 40 and 45).

YE_i is the linear mode variable of the ordinate scale for Largest Extreme Value distribution for the i^{th} data point.

YL_i is the linear mode variable of the ordinate scale for Logistic distribution for the i^{th} data point.

YN_i is the linear mode variable of the ordinate scale for Normal distribution for the i^{th} data point.

α is the intercept of the least squares line on the Y-axis. (See Equation 6.3 in Section 6.1.1 on Page 28).

αN, αL, αM, αE, and αW are the intercepts of the least squares lines fitted to Normal, Logistic, Largest Extreme Value, Smallest Extreme Value and Weibull distributions respectively.

β is the slope of the least squares line. (See Equation 6.2 in Section 6.1.1 on Page 28.)

βN, βL, βM, βE, and βW are the slopes of the least squares line fitted to Normal, Logistic, Largest Extreme Value, Smallest Extreme Value, and Weibull distribution respectively.

R is the correlation coefficient. (See Equation 6.6 in Section 6.1.3 on Page 29)

RN, RL, RM, RE, and RW are the correlation coefficients of Normal, Logistic, Largest Extreme Value, Smallest Extreme Value, and Weibull distributions respectively.

ID is an identification number for each data set.

LC_j is the logarithm of life j at which the fatigue strength distribution is desired.

$LST_{j,i}$ is the logarithm of fatigue strength at a given life j for a given data point i.

SN is the scatter of fatigue strength at a given life.

DEV is the standard deviation.

DX and DR are the differences between the two consecutive assumed values of X_o for the Weibull case.

ADX is the absolute value of DX.

DR is the difference between the two consecutive values of correlation coefficients corresponding to the two assumed values of X_o for the Weibull case.

A-4.2 EXPLANATION OF THE FLOW CHART.

The flow chart of the computer program used to determine the fatigue strength distribution was made up of three parts. In the first part of this program, the scatter in the life was converted into the scatter in the fatigue strength, and the y-ordinate of non-linear mode variables into the linear mode variables for each distribution (For example, P was converted to $\ln \ln \frac{1}{1-P}$ for the Weibull case). In the second part, the distribution functions (Weibull, Normal, Logistic, Largest Extreme Value and Smallest Extreme Value) were fitted to these strengths data simultaneously, and the one with the highest degree of fit was the best fitting distribution. The part three is an external Function Fit which was used in part one and part two to fit the least squares lines to the data. As shown in Section A-4.3, blocks were made around different sections of each of these three parts. The specific functions of each of these blocks in the total program are discussed in the following sections.

A-4.2.1 Part One - Conversion of Life Data to Strength Data and Non-Linear Mode Variables to Linear Mode Variables.

Block 1: The function of this block is to store all the necessary information and the various symbols used in this computer program. The program will be rejected in either case when number of data points (N) is larger than 40 or number of lives (m), at which the strength distribution is determined, is larger than 11. (See the flow chart in Section A-4.3).

Block 2: For some data, where the units of stress (US) values are in tons/in^2, killograms/in^2 etc., and the modes of stress (U) in terms of range of stress, etc., these are converted to the units in psi and the mode of stress in completely reversed stress. This is done for each data point in a given data set.

Block 3: Non-linear mode of y co-ordinate of each data point (in this case the median rank value (P) assigned to each data point) is converted into the linear mode of y co-ordinate (e.g. $\ln \ln \frac{1}{1-P}$ for the Weibull case). This is done for all the four distribution functions.

Block 4: In some data if the units of life are in terms of, say, hours or number of reversals, these are converted into cycles. This is done for each data point. The

values of stress and life are converted into the logarithm of stress (log S) and logarithm of life (log N).

Block 5: Using the External Function Fit (as discussed in Section A-4.2.3 and the flow chart shown in A-4.3.3) 1 least squares line ($Y = \alpha + \beta \underline{X}$) is fitted through these data points log (S) and log (N) found in Block 4, and the values of α and β is determined in terms of log α and log β.

Block 6: Using the values of α and β as found by Block 5, and the procedure as discussed in Section 6.2, page 31, the scatter in strength in terms of logarithm of strength ($LST_{j,i}$) at a given life j is determined.

A-4.2.2 Part Two - Determination of the Best Fitting Distribution.

Block 7: The values of logarithm of strengths [log (s)] at a given life (as found in Block 6) are arranged in an increasing order, and they are then converted from log (S) to S.

Block 8: Using the strength values as found from Block 7 and the information from Block 3, the distributions such as Normal, Logistic, Largest Extreme Value and Smallest Extreme Value are fitted (as discussed in Section 6.5) by aid of the External Function Fit discussed in Section A-4.2.3. The values of the correlation coefficients, R, for each of these distribution are then computed.

Block 9: As discussed in Section 6.5.1 (on Weibull distribution,) it is necessary to determine the value of $\underline{X}_0$, the lower bound of strength, before fitting the Weibull distribution to the data. In this block, the initial value of $\underline{X}_0$ is assumed in the manner shown.

Block 10: Other values of X_0 subsequent to the one assumed in Block 9 are assumed, and the magnitude of the new values of $\underline{X}_0$ depends on the magnitude of the previous ones, as shown in this block.

Block 11: Once a value of $\underline{X}_0$ is assumed, the values of $\underline{X}_i = \ln (x_i - \underline{X}_0) = \ln (SN_i - \underline{X}_0)$ are found. Using the value of $\underline{X}_i$ and YW_i (as found from Block 3). The Weibull distribution is fitted to these data by External Function Fit and the corresponding values of the parameters α and β of the least squares line ($Y = \alpha + \beta \underline{X}$) and the correlation coefficient, R, are computed. This is

repeated twelve times and twelve values of $\underline{\overline{X}}_o$ and their corresponding values of α, β, and R are computed. (Note: The number of repetitions, twelve, was chosen arbitrarily).

Block 12: Out of these twelve values of the correlation coefficients which has the maximum value (the best fit) is selected, and its corresponding value of $\underline{X}_o$ is taken as the "true" value of the lower bound of strength $\underline{\overline{X}}_o$.

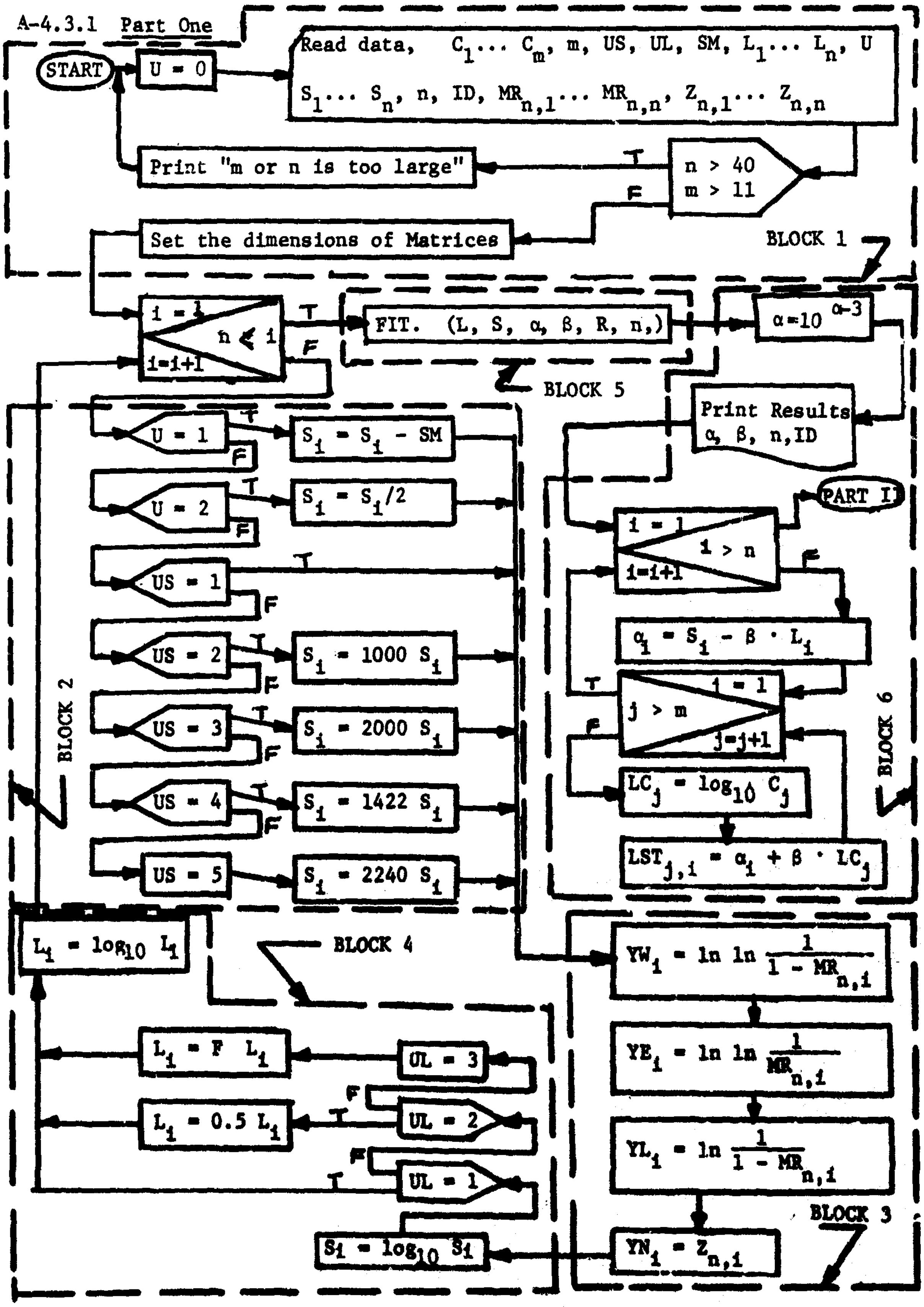
Block 13: The fatigue strength distributions (such as, Weibull, Normal, Logistic, Largest Extreme Value and Smallest Extreme Value), the values of their parameters (in units of KSi where appropriate) and their corresponding values of correlation coefficients are printed out. From this information computer also prints out the name of the best fitting distribution.

A-4.2.3 Part Three - External Function Fit

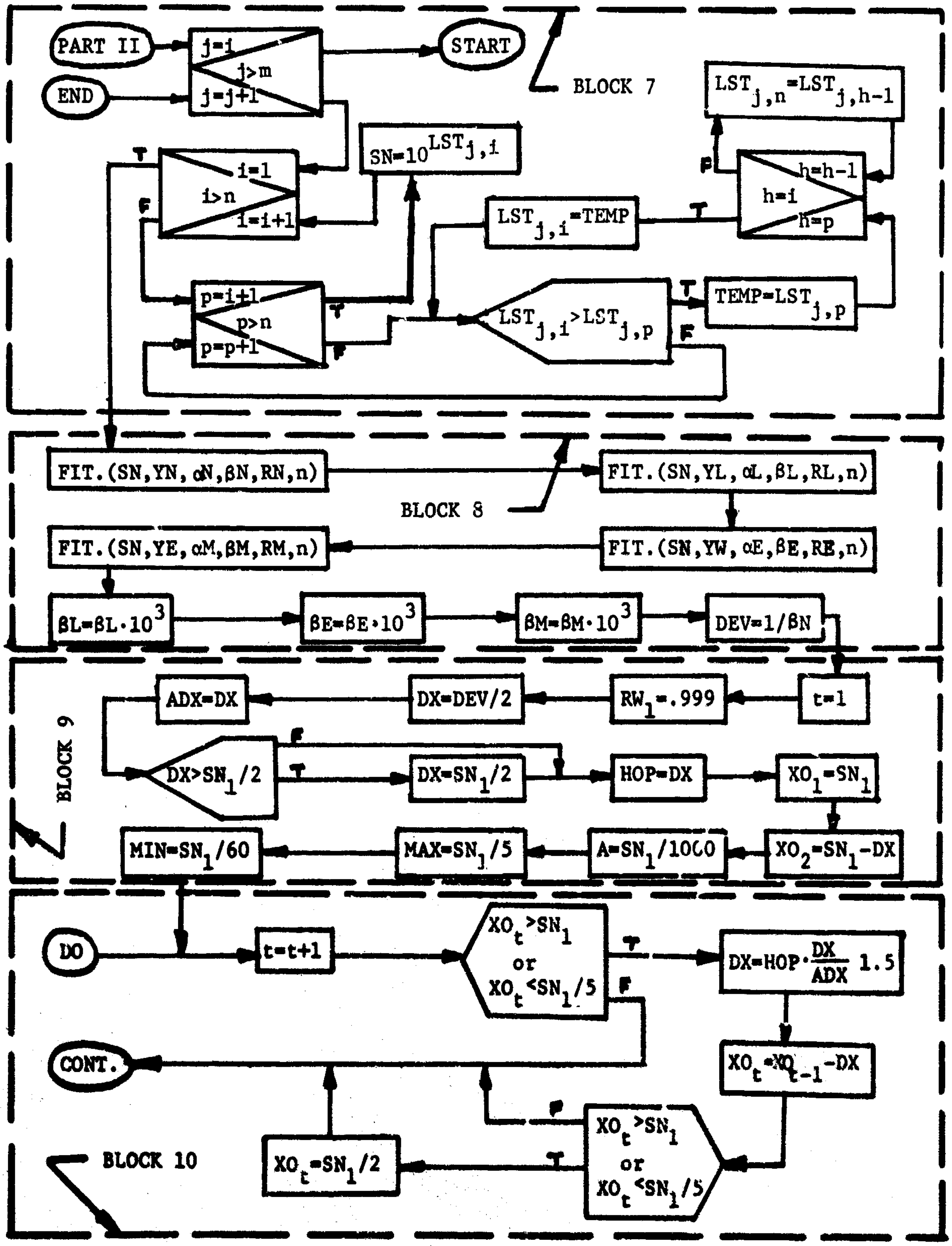
Block 14: External Function Fit is used in Part-one and Part-two of the flow chart to fit a least squares line ($Y = \alpha + \beta\underline{\overline{X}}$) to a set of data points where the values of α and β are computed using Equations (6.2) and (6.3) given on page 28. The corresponding value of the correlation coefficient is then calculated using equations (6.6), (6.7), and (6.8) as given on page 29.

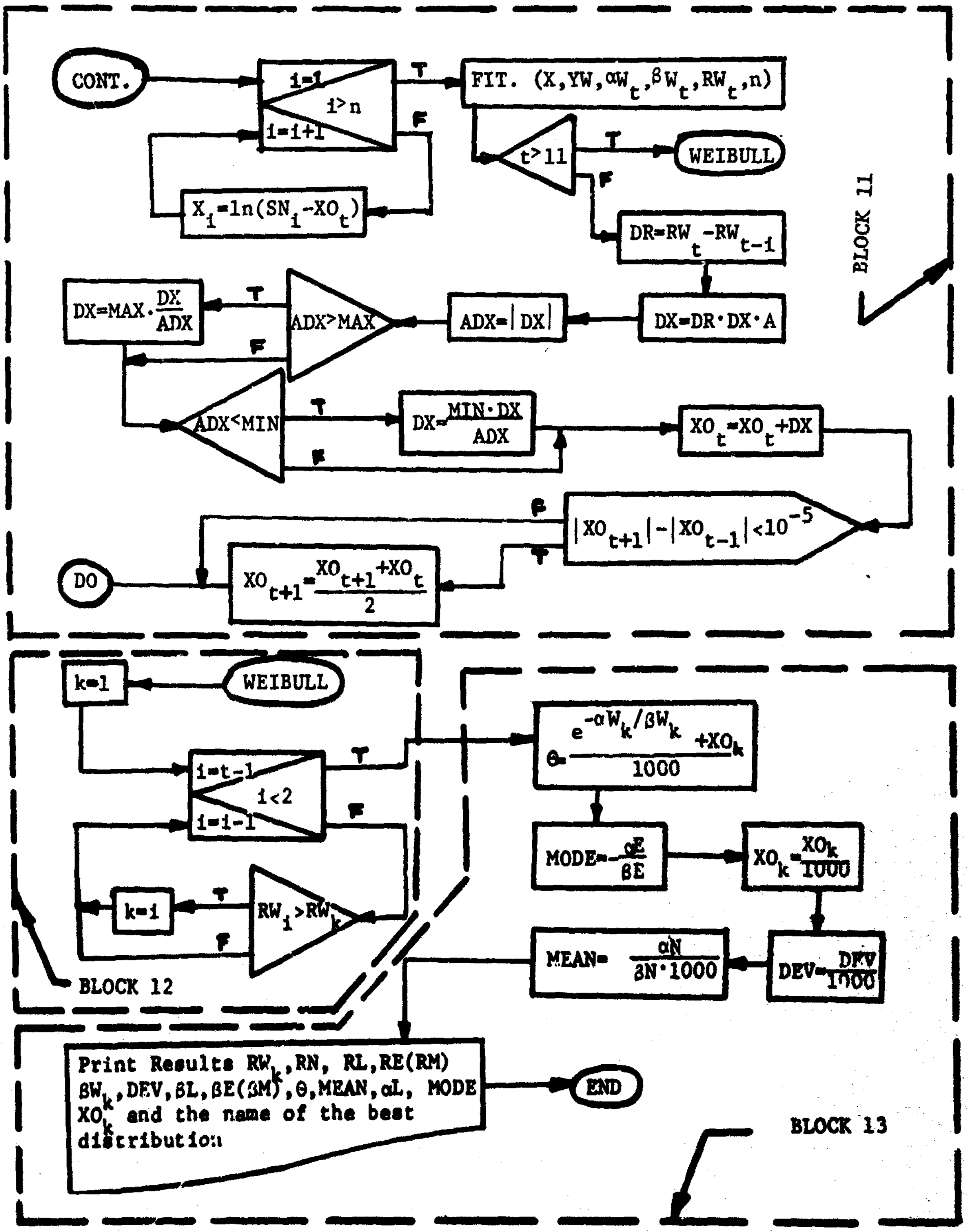
A - 4.3 THE FLOW CHART

A-4.3.1 Part One



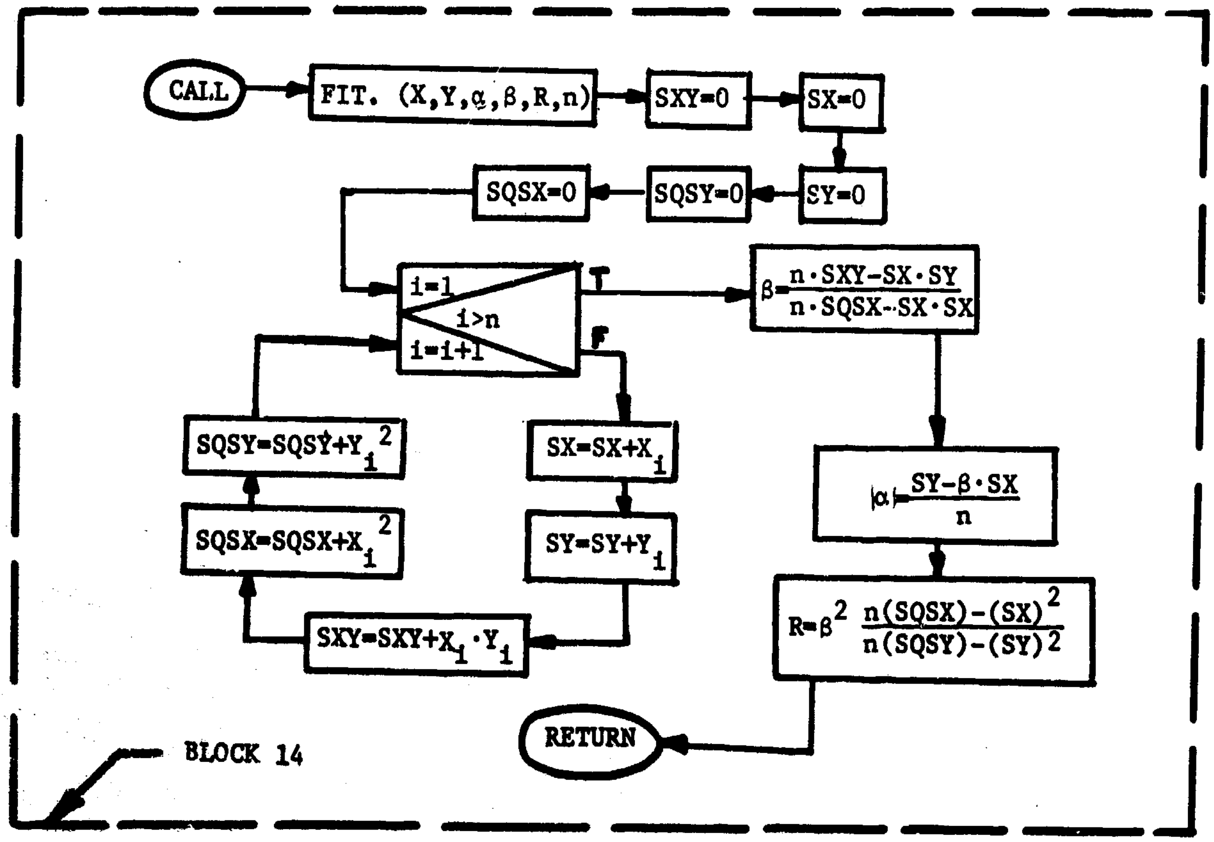
A-4.3.2 Part Two





CONT.
i=1
i>n
i=i+1
T
F
FIT. (X,YW,αW_t,βW_t,RW_t,n)
t>11
WEIBULL
X_i=ln(SN_i-XO_t)
DR=RW_t-RW_t-1
BLOCK 11
DX=MAX·DX/ADX
ADX>MAX
ADX=|DX|
DX=DR·DX·A
ADX<MIN
DX=MIN·DX/ADX
XO_t=XO_t+DX
|XO_t+1|-|XO_t-1|<10^-5
DO
XO_t+1=(XO_t+1+XO_t)/2
k=1
WEIBULL
i=t-1
i<2
i=i-1
k=i
RW_i>RW_k
BLOCK 12
θ=(e^(-αW_k/βW_k)+XO_k)/1000
MODE=-αE/βE
XO_k=XO_k/1000
MEAN=αN/(βN·1000)
DEV=DEV/1000
Print Results RW_k,RN, RL,RE(RM) βW_k,DEV,βL,βE(βM),θ,MEAN,αL, MODE XO_k and the name of the best distribution
END
BLOCK 13

A-4.3.3 External Function Fit



UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Michigan Ann Arbor MI 48104	2a. REPORT SECURITY CLASSIFICATION UNCL 2b. GROUP N/A

3. REPORT TITLE
Reliability Prediction-Mechanical Stress/Strength Interference (Nonferrous)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report - March 1967 - August 1968

5. AUTHOR(S) (First name, middle initial, last name)
Charles Lipson, Ralph C. Disney, Narendra J. Sheth, Mehmet Altun

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1969	450	16

8a. CONTRACT OR GRANT NO. F30602-67-C-0204 b. PROJECT NO. 5519 c. Task No. 551902 d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RADC-TR-68-403

10. DISTRIBUTION STATEMENT
This document is subject to special export controls and each transmittal to foreign governments, foreign nationals, or representatives thereto may be made only with prior approval of RADC (EMERR), GAFB, NY 13440.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Donald W. Fulton - Project Engineer	Rome Air Development Center (EMERR) Griffiss AFB NY 13440

13. ABSTRACT

This study was addressed to the development of a practical engineering tool based on the stress/strength interference theory to be used for designing and predicting the reliability of nonferrous material parts subjected to fatigue loading.

Fatigue data was gathered for 111 nonferrous materials which was converted to strength data to obtain the scatter of strength at a given life. A computer program was used to determine the distribution of the data (i.e., Weibull, Normal, Logistic, LEV and SEV).

The required stress distribution is obtained by converting the stress spectrum, known or assumed, to a zero mean stress spectrum using the Goodman diagram. The required stress spectrum, expressed in terms of equivalent stress, is obtained using Miner's rule.

In this study the interference of two distributions is expressed as an integral which was evaluated using an IBM Computer 360. Tabular values are given for Normal/-Weibull, Normal/Largest Extreme Value and Normal/Smallest Extreme Value distributions.

In order to illustrate the application of the interference technique two examples are presented and solved.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reliability Distribution						
Mechanical Components						
Stress/Strength Interference						
Fatigue						

UNCLASSIFIED

Security Classification

AFLC—Griffiss AFB NY 11 Jul 69—[illegible]